

July 5, 1938.

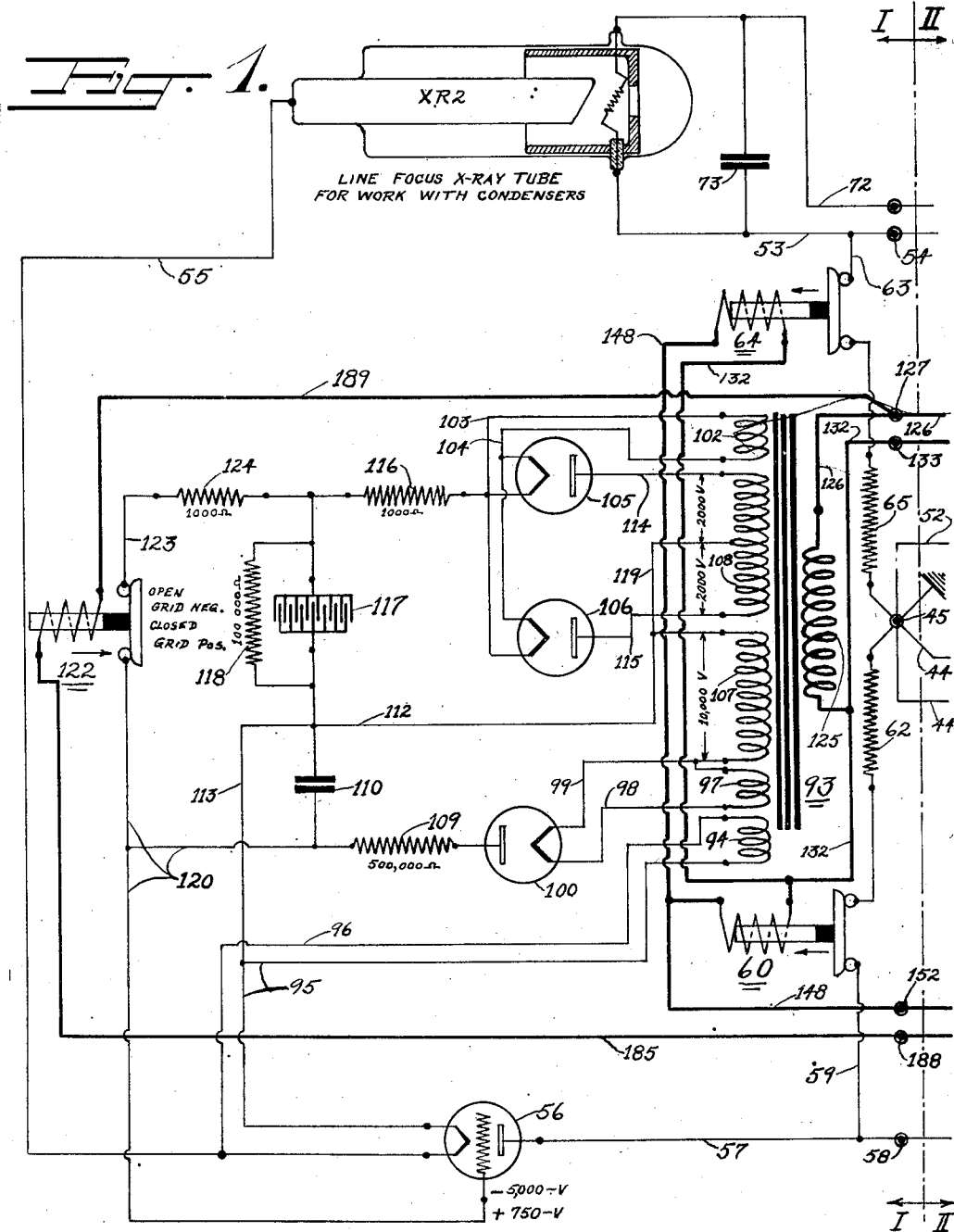
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2,123,018

X-RAY SYSTEM

Filed Dec. 30, 1933

3 Sheets-Sheet 1



INVENTORS
MONTFORD MORRISON
ALFRED SIMON
BY *M. F. Rege*
ATTORNEY

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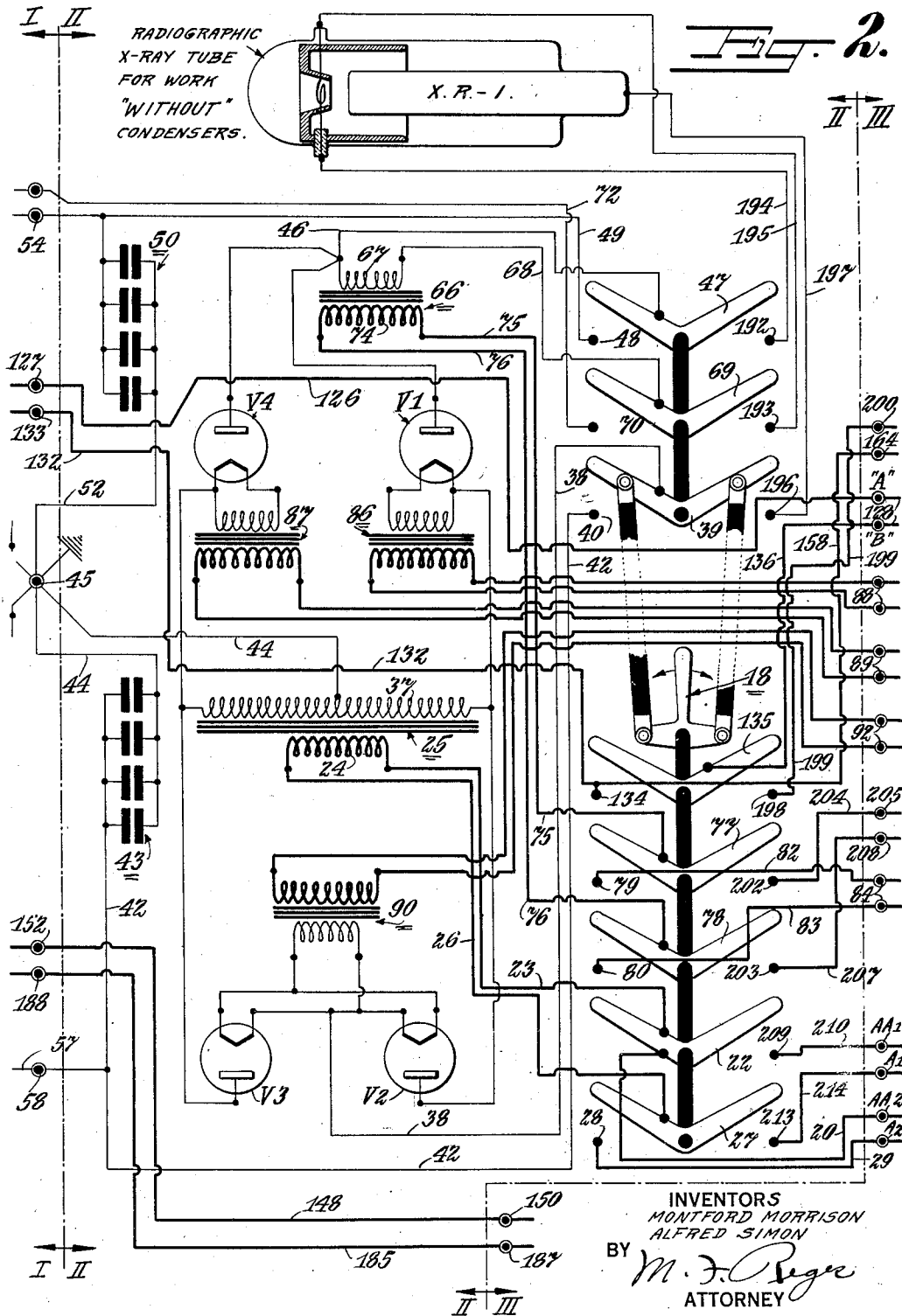
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X-RAY SYSTEM

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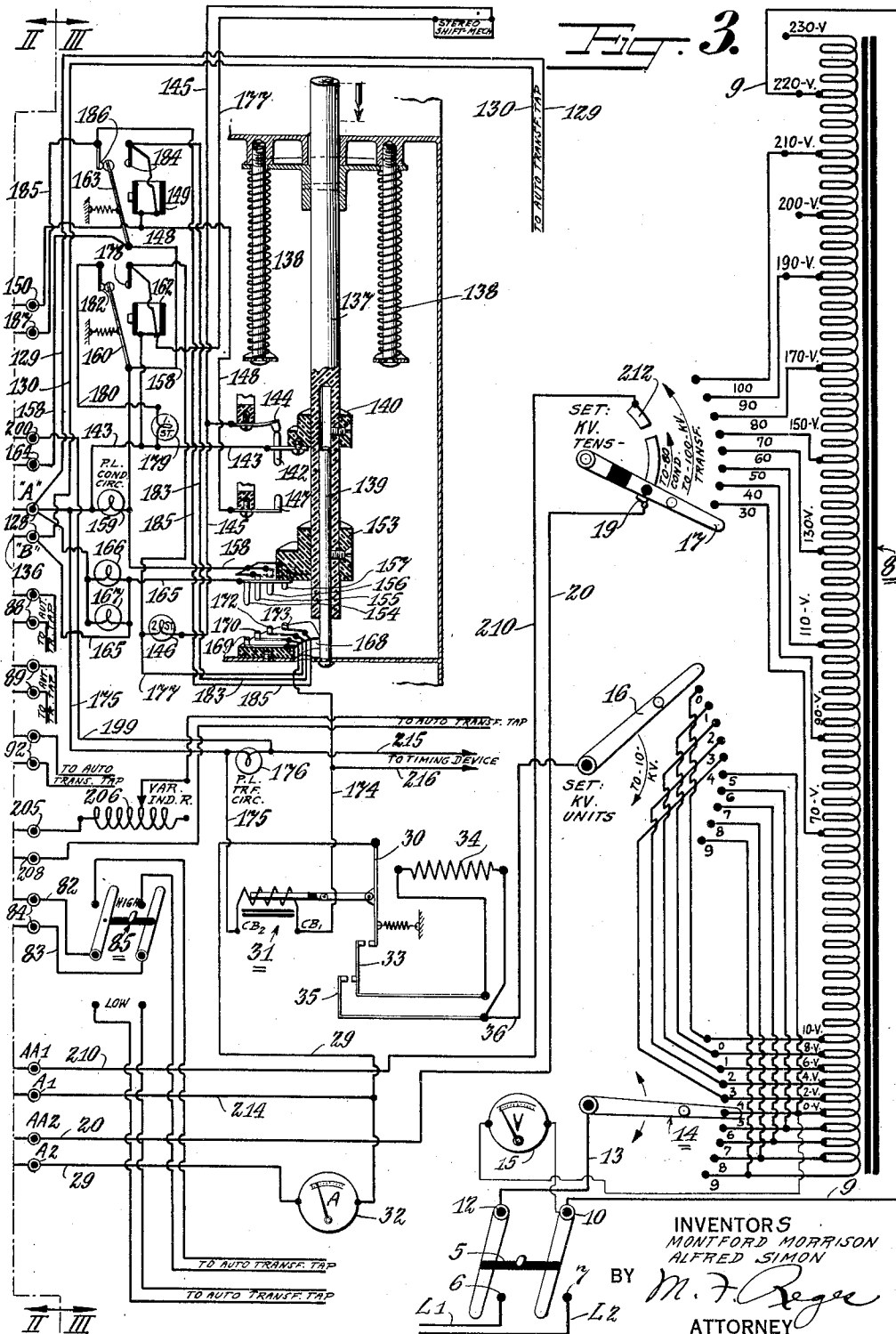
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X-RAY SYSTEM

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UNITED STATES PATENT OFFICE

2,123,018

X-RAY SYSTEM

Montford Morrison, Montclair, N. J., and Alfred Simon, Elmhurst, N. Y., assignors, by mesne assignments, to Westinghouse X-Ray Company, Inc., a corporation of Delaware

Application December 30, 1933, Serial No. 704,618

26 Claims. (Cl. 250—34)

Our invention relates to X-ray systems and has particular reference to such systems for the taking of short exposure X-ray photographs together with a control system for operating the high tension X-ray system.

In the prior art various systems for the taking of so-called short exposure or instantaneous photographs are known. In order to obtain sufficient energy for the X-ray tube for such short periods of energization thereof condensers are usually utilized for storing the requisite energy, which are suddenly caused to discharge through the X-ray tube. These systems are, however, subject to numerous objectionable features the principal one of which is the manner of causing the discharge of the storage condensers.

The condenser in the system is charged to the amount desired which when reached causes break-down of a series connected spark gap and discharge of the condenser through the X-ray tube with a resulting X-ray photograph. The resistance of these spark gaps varies with climatic conditions thus rendering the amount of the energy storable in the condensers uncertain and upon the condenser reaching its maximum, leakage across the gap occurs before complete discharge resulting in a non-uniform emission of X-radiation.

Another system well known to the art is that of maintaining the temperature of the thermionic cathode below saturation until the condenser is completely charged and then suddenly allowing the cathode to be heated to or above the saturation value enabling discharge of the condenser through the X-ray tube. This system likewise causes a leakage of the condenser before complete discharge thereof in the same manner as the aforementioned system employing a spark-gap and in addition an appreciable time lag follows closure of the switch before the cathode reaches saturation which is lost to the actual exposure time.

It has also been proposed to control the discharge of a condenser in an X-ray system by utilizing a discharge device connected in series with the X-ray tube and condenser and controlling the flow of energy therethrough by means of a magnetic field. In such a system, however, due to the high potential heavy current energy to which the X-ray tube is subjected the magnetic field cannot successfully be maintained at sufficient magnitude to entirely prevent the flow of energy through the discharge device. This results in a constant energization of the X-ray tube with attendant emission of

X-rays, but of varying intensity which is detrimental to a radiographic film. Moreover, the source of energy for energizing the magnetic winding must be properly insulated from the high potential energy flowing through the discharge device to prevent accidental shocks to patient and operator thus presenting a further objectionable feature to this particular system.

In the copending application of Montford Morrison, Serial No. 582,933 filed December 24, 1931 an X-ray system for the taking of short exposure or so-called instantaneous X-ray photographs is shown and described which obviates the objectionable features present in these prior art systems. In this novel system discharge of the storage condensers is positively prevented by the employment of a three electrode discharge device, the main electrodes of which are connected in series with the X-ray tube and the condensers and are thus subjected to the same voltage-current characteristics as the X-ray tube. By impressing a sufficiently high negative potential upon the grid or control electrode from an auxiliary source of energy, the high tension energy is prohibited from flowing between the main electrodes of the discharge device and consequently from the condensers to the X-ray tube.

When it is desired to take a radiographic exposure the polarity of the potential impressed by the auxiliary source upon the control electrode of the discharge device is changed from negative to positive causing the instantaneous discharge of the condensers through the discharge device and X-ray tube resulting in a radiographic exposure of predetermined uniform intensity.

Our present invention constitutes an improvement upon the system shown in this copending application and incorporates a novel manner of control of the same. In this prior Morrison application the energy for supplying the X-ray tube for the taking of the X-ray photograph is stored in condensers in the same manner as in the present application. However, the quantum of energy stored in these condensers is largely dependent upon the time period of closure of the switch controlling the high tension transformer and the operator must carefully scrutinize the indicating meters during charging of the condensers in order that the desired quantum of energy is stored therein or the proper setting for the charging rate must be determined empirically before an actual exposure is made.

It is also possible that in the event the switch

controlling the high tension transformer should be left closed upon completion of an exposure and the operator or patient accidentally contact certain parts of the apparatus serious shocks may result. Moreover, when the condensers are caused to suddenly discharge through the controlling discharge device and X-ray tube this rush of energy frequently causes deleterious results to the filamentary cathodes of both of these tubes which, if not entirely disrupting the same, considerably shortens the useful life thereof.

In the present invention we provide a duplex X-ray generator which constitutes what may be conventionally termed a condenser discharge system or single impulse generator and a pulsating X-ray generator. In operating the system as a condenser discharge generator numerous advantageous results are obtainable with our present system which have not been possible with such systems of the prior art. For example, in the conventional so-called condenser discharge systems three variables must always be considered in the taking of X-ray photographs, namely, the energy supplied to the X-ray tube expressed in milliamperes, the time of energization of the X-ray tube, and the potential expressed in kilovolts. It is usual in the X-ray art to express the product of the first two variables in terms of milliampereseconds and it will accordingly be so termed throughout our specification and claims.

The quantity of electrical energy stored in condensers, although generally expressed in the electrical art in coulombs or microcoulombs, is frequently expressed in the X-ray art in milliampereseconds. In storing a condenser at a predetermined potential a desired amount of energy or milliampereseconds can be stored therein by fixing a definite ratio between the charging potential and the condenser capacity which governs the quantity of energy or milliampereseconds. In our present condenser discharge system we fix this ratio at one to one, thus if the condensers having a total capacity of 1 microfarad are caused to be charged at 80 k. v. they will store 80 milliampereseconds of energy. This energy may likewise be discharged from these condensers at any desired rate i. e. assuming 80 milliampereseconds are stored in the condensers the X-ray tube may be energized at 800 milliamperes for $\frac{1}{10}$ of a second or 4000 milliamperes for $\frac{1}{40}$ of a second.

In our novel system we dispense with the necessity of a timing device for controlling the discharge of the condensers and utilize the filament heating for the X-ray tube to control the discharge of the condensers and consequently the exposure period. Thus it can be readily appreciated that the higher the temperature of the cathode of the X-ray tube the faster the discharge and period of exposure, and the cooler the cathode the slower the discharge and longer the period of exposure. The amount of energy delivered to the X-ray tube is very precisely measured, as before explained, by regulating the milliampereseconds stored in the condensers and the timing of the X-ray exposure accordingly ceases to be a factor due to this predetermined amount being delivered to the X-ray tube thus dispensing with the necessity for precise time control. It frequently happens, however, that an extremely fast speed of exposure is desired, over that required for usual routine exposures, in order to radiograph at rest some particular portion of the human anatomy, which is normally in motion, such as the heart and lungs. Accordingly under

these conditions we enable the cathode heating temperature to be increased in order to pass the energy through the X-ray tube in a shorter period of time.

In dispensing with time and milliamperes as separate factors in our present system a timing device is not only unnecessary, but likewise a milliampere meter is not required, which greatly simplifies the system for the operator. This leaves only the factors of distance and potential to be determined and, as the former is usually predetermined by the manufacturer upon a scale for the various parts of the body, the concern of the operator is limited to that of the proper kilo-voltage or potential. To further simplify our system we provide the auto-transformer which regulates the energization of the high tension transformer and consequently the charging rate of the associated condensers with dials graduated in numerals.

These dials are operable with the auto-transformer control knobs and the latter are connected to the auto-transformer in such a manner that not only the potential is regulated in 10 kilovolt steps but in units as well. The operator can, therefore, readily set the auto-transformer for any desired kilovoltage from 1 to 99 and the correct milliampere-seconds will be stored in the condensers.

It must be appreciated, however, that the setting of the auto-transformer is initially calibrated at a fixed line voltage at the factory and in order for this to remain uniform the line voltage must likewise be equivalent to that at the time of calibration. In order to assure this setting we provide our system with a voltage regulator together with a voltmeter having a single graduation. The operator need only adjust this voltage regulator until the needle of the voltmeter is on the single graduation which indicates that the auto-transformer is receiving the proper voltage and the setting of the energy for the high tension transformer and condensers unfailingly follows with absolute precision.

When the system is in readiness for an exposure the discharge of the condensers is caused by the controlling discharge device in the same manner as in the aforementioned copending Morrison application. However, in order to prevent the sudden rush of energy from the condensers through the controlling discharge device or "trigger tube," as we prefer to term it, and the X-ray tube, from deleteriously affecting these tubes, we provide means to suppress this sudden flow for a short period of time to allow the gradual rise in the flow of energy as hereinafter more fully described.

When not actually utilized for the purposes of an exposure we further provide our present system with means to render it shockproof to prevent injury resulting to operator or patient should they accidentally contact the apparatus even though the main switch may have been inadvertently left in the closed position. The entire control for the high potential portion of our condenser discharge machine is centralized and remotely disposed from the high potential portion. Upon setting the controls for the desired amount of energy, operation of the entire system automatically follows actuation of a single control button in predetermined sequence and at the proper time, thus producing a simplified and efficient condenser discharge or single impulse X-ray generator.

Under certain circumstances a different tech-

nic is required wherein it is preferable to utilize a pulsating X-ray generator instead of a single impulse or condenser discharge generator. When this necessity arises our system may be readily converted from one form of generator to the other by manipulation of a single switch as hereinafter more fully set forth. The unitary remotely disposed control stand is operable to control the system under either condition of operation thus maintaining all the novel features as hereinbefore mentioned relative to our system when utilized as a single impulse or condenser discharge machine.

It is accordingly an object of our present invention to provide an X-ray system for the taking of short exposure X-ray photographs wherein the quantum of energy for the energization of the X-ray tube can be definitely determined by the operator before the actual exposure.

Another object of our invention is the provision of an X-ray system for the taking of short exposure X-ray photographs wherein the system is automatically rendered shockproof when not actually in operation for the taking of an exposure, thus obviating the possibilities of disastrous shocks resulting to operator or patient.

Another object of our invention is the provision of an X-ray system for the taking of short exposure X-ray photographs wherein a discharge device is employed for controlling the energy from a high tension source to the X-ray tube and in which the sudden rush of energy through the discharge device and X-ray tube is prevented from deleteriously affecting either of these tubes.

Another object of our invention is to provide an X-ray system for the taking of short exposure X-ray photographs wherein the operation of the system is remotely controlled and is automatically responsive to actuation of the control circuit by the operator.

Another object of our invention is the provision of a novel control system for short exposure X-ray photographic systems wherein the complete operation of the X-ray system occurs in a predetermined sequence and at predetermined periods of time.

Another object of our invention is the provision of an X-ray system for taking short exposure X-ray photographs of the single impulse or condenser discharge type which may be readily converted to an X-ray system of the pulsating type.

A further object of our invention is the provision of a novel control system for short exposure X-ray photographic systems wherein the operation of the X-ray system follows actuation of the control system automatically with minute precision and in which the operation of the entire apparatus is rendered exceptionally simple thus dispensing with the necessity of a skilled operator.

Still further objects of our invention will become apparent to those skilled in the art by reference to the accompanying drawings in which

Figure 1 is a diagrammatical representation of the high tension circuit control portion of an X-ray system together with certain safety features thereof,

Fig. 2 is a diagrammatical representation constituting in the main the high tension portion of our X-ray system, and

Fig. 3 is a diagrammatical representation of the low tension and control portions of our system which in the main is housed within and constitutes the control stand therefor.

Referring now to the drawings in detail wherein each sheet discloses a portion of our X-ray system which, when placed together in the order of the figures as above described reading from left to right, constitutes our entire system, we have shown in Fig. 3 an alternating current source of electrical energy of the usual commercial potential, such as the conductors L1 and L2. A main line switch 5 extends through the panel of the control stand and is provided with a pair of terminals 6 and 7 to which the alternating current source is connected. An auto-transformer 8 has one of its ends connected, by means of a conductor 9, to one of the main line switch terminals 10 and a further terminal 12 of the main line switch is connected, by means of a conductor 13, to the adjustable arm of a voltage regulator 14.

This voltage regulator is provided with a series of taps, as indicated, for the purpose of connecting one side of the supply source to any one of a plurality of turns of the auto-transformer which are calibrated in 2 volt steps. A voltmeter 15 having but a single graduation is connected to the switch terminal 10 and to one tap of the auto-transformer which we have designated as zero volts. When the line voltage of the supply source L1, L2 is normal, which is assumed and consequently calibrated for 220 volts, the voltmeter 15 will record this voltage with the pointer thereof aligning with the single graduation of the dial.

If the line voltage is above or below standard of 220 v. the line voltage regulator 14 is moved by 2 volt steps, above or below the zero volt tap, to increase or decrease the voltage of the auto-transformer to thus cause the necessary variation in the pointer of the voltmeter until it aligns with the single dial graduation which then sets the entire system to the correct voltage for which it was previously calibrated.

The panel of our control stand is provided with a pair of adjustable knobs that are adapted to rotate a pair of arms 16 and 17, respectively, each of which engage various taps constituting the output terminals of the auto-transformer 8. The arm 16 engages various taps of the auto-transformer for the purpose of selecting various output voltages of a fine degree, such as units of voltage, whereas the arm 17 is arranged to select various taps of a large range calibrated as indicated in ten volt steps. A pair of dials (not shown) are arranged to rotate with the arms 16 and 17 and are marked with numerals, corresponding in terms of kilo-voltage, which are so illuminated that the operator can set the auto-transformer for any desired kilo-voltage in tens and units ranging from 1 to 99 kilovoltages, and such setting is clearly visible at the control stand.

A double throw switch 18 (Fig. 2), which is provided with a plurality of blades, is arranged when moved to the left as viewed from the figure to render our system a single impulse generator or condenser discharge machine and in its other position converts the system to a pulsating generator as hereinbefore noted. For the sake of simplicity our system will first be described when functioning as a single impulse or condenser discharge system with the switch 18 moved to the left as indicated by the arrow.

The auto-transformer arm 17 is in electrical contact with a segmental contact strip 19 in order that it be made conducting whenever the arm engages one of its associated auto-transformer taps and a conductor 20 connects this strip 19 to one of

the switch blades 22 of the switch 18 through a terminal connection AA2. A second conductor 23 is likewise connected to this same switch blade 22 and extends to the primary winding 24 of a high tension transformer 25. The other end of this primary winding 24 is in turn connected, by means of a conductor 26, to another switch blade 27 of the switch 18, and, when this switch is in the position assumed, is thus connected to a switch terminal 28.

This latter switch terminal 28 is connected, by means of a conductor 29 and terminal connection A2, to the normally open armature 30 of a relay 31, with a charging indicator 32 constituting a modified form of ammeter as hereinafter more fully explained interposed in this conductor 29. A normally open contactor 33 of the relay 31 is connected to one side of a resistance element 34 and a further normally open contactor 35 is connected to the other end of this resistance element 34 and also by means of a conductor 36 to the unit auto-transformer arm 16. Accordingly the circuit for energizing the primary winding 24 of the high tension transformer 25 is normally interrupted and is not completed until operation of the relay 31.

The high tension transformer 25, shown in Fig. 2, is provided with a secondary winding 37 one end of which is connected to the cathode of a rectifying valve V1 and the anode of a second rectifying valve V2 and the remaining end of this winding is likewise connected to the anode and cathode, respectively, of a pair of rectifying valves V3 and V4. A conductor 38 connects the cathodes of both valve tubes V2 and V3 to a switch blade 39 which in turn is connected to a switch terminal 40 when the switch 18 is in the left hand position.

A further conductor 42 connects the terminal 40 to one side of a bank of condensers 43 with the input circuit for the latter being completed through a conductor 44, which extends through a grounded junction 45, to the mid-point of the secondary winding 37.

In a similar manner the anodes of the valve tubes V1 and V4 are both connected, by means of a conductor 46, to a switch blade 47 which in turn is connected to a switch terminal 48 when the switch 18 is in the assumed position. A conductor 49 then connects the terminal 48 to one side of a bank of condensers 50, similar to the bank 43, and the input or charging circuit therefor is completed by a conductor 52 connected to the grounded junction 45 and thus to the midpoint of the secondary winding 37. This portion of our high tension circuit for charging the condensers 43 and 50 will be readily recognized as the usual full wave rectifying system and further description of the manner of current flow therethrough during each half wave of the alternating current cycle, upon energization of the transformer 25 is deemed unnecessary as it is well known to the art.

An X-ray tube XR2 (Fig. 1) is provided for generating X-rays upon discharge of the condensers 43 and 50 and has its cathode connected by means of a conductor 53 through a conductor terminal 54 to the conductor 49 and thus to the condensers 50. The anode of the X-ray tube XR2 is connected by means of a conductor 55 to the cathode of a three electrode controlling or trigger tube 56, as hereinbefore mentioned, with the anode of this trigger tube being in turn connected, by means of a conductor 57 and through a conductor terminal 58, to the conductor 42 and thus to the condensers 43. During the accumulation of a charge in the condensers 43 and 50 from the high tension trans-

former 25 any discharge or leakage through the X-ray tube is prevented by impressing a high negative potential upon the grid of the trigger tube from an auxiliary source of energy which is independent of the high tension source.

When it is desired to take a radiographic exposure the potential impressed upon the grid is instantaneously reversed to a positive polarity without interrupting the auxiliary circuit by the operation of a remotely controlled relay as hereinafter more fully set forth.

The condensers 43 and 50 are also provided with a further output circuit which constitutes a novel safety feature of our present system. A conductor 59 is connected to the conductor 57, and thus to one side of the condensers 43, and extends through the contact terminals of a normally closed relay 60 and a fixed resistance 62 to the grounded junction 45 to which the remaining side of these condensers is also connected.

In a like manner a conductor 63 is connected to the conductor 53, and thus to one side of the condensers 50, and also extends through the contact terminals of a normally closed relay 64 and a fixed resistance 65 to the grounded junction 45 to which the remaining side of these condensers 50 is also connected. Accordingly any energy left in these condensers upon completion of each exposure is automatically discharged to ground thus obviating any possibilities of accidental shocks to a patient or operator.

In order to supply heating current for the cathode of the X-ray tube XR2 we provide a low tension transformer 66 with one end of the secondary winding 67 thereof connected to the conductor 45 and thus to one side of the cathode of the tube through switch blade 47, terminal 48, and conductors 49 and 53. The remaining end of this low tension secondary winding 67 is connected by means of a conductor 68 which extends to a switch blade 69 in turn connected to a switch terminal 70 when the switch 18 is in the left hand position. A conductor 72 then connects the switch terminal 70 to the other side of the cathode of the X-ray tube XR2 and a condenser 73 is connected in parallel relation with respect to the cathode and its heating source or secondary winding 67 which functions to prevent deleterious results to the cathode upon energization of the tube by discharge of the condensers 43 and 50.

The primary winding 74 of the heating transformer 66 is connected, by means of a pair of conductors 75 and 76, to switch blades 77 and 78, respectively, which establish contact with a pair of terminals 79 and 80 when the switch 18 is in the left hand position as viewed from Fig. 2.

These latter terminals are in turn connected, by means of a pair of conductors 82 and 83, through conductor terminals 84 to the blades of a double throw switch 85 as shown in Fig. 3 provided in the control stand panel. Each of the supply terminals of this switch 85 is connected to a suitable source of electrical energy such as the auto-transformer 8, but to taps thereof of different voltage. This is to enable the switch 85, when in the position indicated as "high", to supply the primary winding 74 of the cathode heating transformer 66 with a higher voltage than normal for the purpose of increasing the speed of discharge of condensers 43 and 50 when it is desired to take an ultra-rapid exposure so as to radiograph at rest a part of the anatomy normally in motion, such as the heart or lungs. On the other hand when the switch

35 is in the position indicated as "low" the heating transformer is energized by a lower voltage for the usual type of radiographic exposures which require a slightly longer period for discharge of the condensers with attendant energization of the X-ray tube XR2.

The thermionic cathodes of the rectifying valves V1 and V4 are supplied with heating current from a low tension source, such as the respective transformers 36 and 37, having their primary windings connected through conductor terminals 38 and 39, respectively, to desired voltage taps of the auto-transformer as indicated for the sake of simplicity "to auto-tr. tap" in Fig. 3. In a similar manner the thermionic cathodes of the rectifying valves V2 and V3 are supplied with heating current from a low tension source, which in this instance, may be a single heating transformer 30 due to the respective cathodes not being connected directly to opposite ends of the transformer secondary 37 and being only alternately conductive. Likewise the primary winding of this transformer is connected through a pair of conductor terminals 32 directly to the appropriate voltage tap of auto-transformer 8 as indicated.

Referring now more particularly to Fig. 1 which discloses our auxiliary source of energy for supplying a negative and positive potential to the control electrode or grid of the trigger tube 56 which is independent of the high tension source, we have shown a high tension transformer 93. A low tension secondary winding 94 is provided upon the core of this transformer and is connected by means of a pair of conductors 95 and 96 to the thermionic cathode of the trigger tube 56. Another low tension winding 97 is wound upon the core of the transformer 93 and is connected, by means of conductors 98 and 99 to the thermionic cathode of a rectifying valve 100, while a still further low tension secondary winding 102 supplies heating current through a pair of conductors 103 and 104 to the thermionic cathodes of a pair of rectifying valves 105 and 106 respectively.

A high tension secondary winding divided into two sections 107 and 108 is provided for generating a positive and negative potential in order that it may be selectively impressed upon the grid of the trigger tube 56. One end of the winding 107, which generates for example 10,000 volts, is connected to the conductor 99 and thus to the cathode of the rectifying valve 100, and the anode of this valve is connected, through a suitable high fixed resistance 109 having a definite ohmic resistance of, for example, 500,000 ohms, to one plate of a condenser 110. The remaining plate of this condenser 110 is connected by means of a conductor 112 to the opposite end of the secondary winding 107, and also by means of a conductor 113 to the conductor 95 and thus to the cathode of trigger tube 56. The winding 108, which generates for example a total of 4,000 volts has one of its ends connected, by means of a conductor 114, to the anode of valve tube 105 and its other end connected, by means of a conductor 115, to the anode of rectifying valve 106.

The thermionic cathodes of both rectifying valves 105 and 106 are connected, through a suitable fixed resistance 116 having a definite ohmic resistance of for example 1000 ohms, to one plate of a condenser 117 having a capacity greater than that of condenser 110 and to one side of another comparatively high fixed resist-

ance 118. The remaining plate of condenser 117 and other terminal of resistance 118 is connected to the conductor 112 which in turn is connected to the mid-point of the winding 102, through a conductor 119. A conductor 120 connects one plate of the condenser 110 and high resistance 109 to the grid of the trigger tube 56 and is also connected to one terminal of a grid contactor relay 122, while another terminal of this relay 122 is connected, by means of a conductor 123 through a fixed resistance 124, to one side of the respective resistances 116, 118 and also one plate of the condenser 117.

The primary winding 125 of the transformer 93 has one of its ends connected, by means of a conductor 126 extending through a conductor terminal 127, to one of a pair of conductor terminals 128, which latter terminals are directly connected by means of a pair of conductors 129 and 130 to "control supply" voltage taps of the auto-transformer 8, as shown by that legend in Fig. 3. The remaining end of primary winding 125 is connected, by means of a conductor 132 through a conductor terminal 133, to a switch terminal 134 of switch 18, which is arranged to be contacted by a blade 135 thereof, when the switch is in the assumed or left hand position, and this conductor 132 likewise extends to one end of the respective windings of the condenser short circuiting relays 60 and 64. The switch blade 135 is in turn connected by a conductor 136 to the remaining conductor terminal of the pair 128 and is thus connected directly to the other side of the "control supply" source of the auto-transformer 8.

As soon as the transformer 93 is energized the relay 122 is simultaneously energized, as herein-after more fully described, which will cause the thermionic cathodes of the trigger tube 56 and the rectifying valves 100, 105 and 106 to be heated by their respective low tension heating sources. Immediately therewith the winding 107 will, during negative half waves of the alternating current cycle, charge the condenser 110 by the circuit extending from one end of the winding 107 through conductor 99, valve tube 100 and resistance 109, to the condenser 110 and thence back to the winding 107 by means of the conductor 112. At the same time a high negative polarity will be impressed upon the grid of the trigger tube 56 by the conductor 120 with respect to the cathode thereof, the latter of which is connected by the conductor 113 to the positive plate of the condenser 110.

The secondary 108 is likewise energized and during one half wave of the alternating current cycle will charge the condenser 117 by a circuit extending from one end of the winding 108, through conductor 114, valve tube 105 and resistance 116 to one side of condenser 117, and thence back to the midpoint of winding 108 through the conductors 112 and 119. During the remaining or reverse half wave of the alternating current cycle the only difference in the charging circuit for the condenser 117 resides in the valve tube 106 becoming conductive in lieu of the valve tube 105. Thus it becomes obvious that charging of the condenser 117 is during the entire alternating current cycle by full wave rectification while the charging of the condenser 110 is half wave rectification.

The energy thus stored in the condenser 117, has at this particular instant, no effect upon the high negative polarity impressed upon the grid of the trigger tube. When it is desired to render

the trigger tube conducting in order to cause current flow between the anode and cathode thereof the relay 122 is merely deenergized thus allowing closure of its contact terminals. This immediately impresses a positive polarity of lesser magnitude upon the grid of the trigger tube from the condenser 117 through resistance 124 and conductors 123 and 120 while the cathode now becomes negative with respect to the grid due to the conductor 113 being connected to the negative plate of the condenser 117. As the condenser 117 is charged only with a maximum of 2000 volts positive from the 4000 volt source while the condenser 110 is charged with 10,000 volts negative from its charging source the difference in magnitude is readily apparent.

Moreover, the reversal of the grid polarity is accomplished without an interruption in the auxiliary source which precludes the high potential current flowing through the trigger tube from inherently building up a negative polarity upon the grid and again preventing current flow. The high ohmic resistance 109 also prevents a negative charge from being impressed upon the grid during closure of the relay 122 and the resistance elements 116 and 124 function to slightly retard the immediate application of the maximum positive polarity to the grid to thus prevent too steep a wave front to the initial surge of current through the trigger tube and consequently the X-ray tube. Upon deenergization of the transformer 93 the resistance 118 functions to absorb the energy left in the condenser 117.

Referring now more particularly to Fig. 3 we provide our control panel with a unitary switch for causing desired operation of our system in a preselected manner and in predetermined sequence. This switch comprises a cylinder 137 normally biased in an upward position, as shown in the figure, by suitable means such as a pair of compression springs 138 secured to the underside of the panel of the control stand. A rigidly secured plunger 139 loosely engages the cylinder 137 of the switch to permit the ingress and egress of air to thus prevent too rapid depression of the switch. An insulated collar 140 is secured to the movable portion of the switch 137 and is provided with a contact member 142 which is connected, by means of a conductor 143, to one of the conductor terminals 128 connected directly to the "control circuit supply" from auto-transformer 8. In the normal or "off" position of the switch 137 the contact member 142 engages a stationary contact member 144 which is connected, by means of a conductor 145, to one side of stereoscopic shifting mechanism, which may be utilized with our system if desired, and also to one side of a pilot light 146 to indicate upon the control panel the particular stereoscopic exposure about to be taken.

During downward movement of the switch 137 the contact member 142 breaks connection with the member 144 and establishes engagement with another stationary contact member 147 which is connected, by means of a conductor 148 to one end of the winding of a relay 149, and through conductor terminals 150 (lower terminal in Fig. 2) and 152 to one end of the respective windings of condenser short circuiting relays 60 and 64. Another insulating collar 153 is rigidly secured to the movable switch member 137 and is provided with a plurality of contact terminals 154, 155, 156 and 157.

The contact terminals 155, 156 and 157 are connected to a common conductor 158 which ex-

tends to one side of a pilot light 159 utilized to give a visual indication upon the control panel when the entire system is set for a single impulse or condenser discharge generator.

This conductor 158 is also connected to the movable armature 160 of a relay 162, employed in conjunction with the stereoscopic shifting mechanism, if utilized, as more fully hereinafter explained, as well as the movable armature 163 of the relay 149 and through a conductor terminal 164 to the switch terminal 134 of the switch 18. The contact terminal 154 is connected by means of a conductor 165 to one side of a pair of pilot lights 166 and 167, which are utilized for the purpose of illuminating the aforementioned auto-transformer dials as well as the indicating meters 15 and 32, and also extends to one of the conductor terminals 128 which constitutes one of the control supply conductors. The other terminals of the pilot lights 166 and 167 are connected directly to the remaining terminal 128 so that it is obvious they are immediately illuminated upon energization of the auto-transformer following closure of the main line switch 5.

A stationary insulating block 168 is rigidly secured to the control stand and is provided with a plurality of contact terminals 169, 170, 172 and 173 so positioned as to be engaged by the respective contact terminals 154, 155, 156 and 157 upon depression of the switch 137. The contact terminal 169 is connected by means of a conductor 174 to one end of the winding of relay 31 with the remaining end of this winding being connected by a conductor 175, to one terminal of a pilot light 176 for giving a visual indication when the system is set as a pulsating generator, and also directly to the supply conductor terminal 128.

Contact terminal 170 is connected, by means of a conductor 177, to the other terminal of pilot light 146 as well as to a contact terminal 178 of relay 162, one end of this relay winding, and to the remaining terminal of the stereoscopic shifting mechanism, with the remaining end of the relay winding being connected to one of the supply conductor terminals 128 by the conductor 143 which is common to this winding and contact terminal 142, as well as to a further stereoscopic pilot light 179 similar to the indicating pilot light 146. This pilot light 179 has its remaining terminal connected by a conductor 180 to a stationary contact terminal 182 which is normally engaged by the movable armature 160 of the relay 162.

The contact terminal 172, also carried by the insulating block 168, is connected by a conductor 183 to a stationary contact terminal 184 of relay 149 which is adapted to be engaged by the movable armature 163 thereof upon energization of the relay, and is also connected to the remaining end of the winding of this relay 149. The remaining contact terminal 173 is connected, by means of a conductor 185, to another stationary contact terminal 186 of relay 149, which is normally engaged by the movable armature 163 thereof, and this conductor also extends, through conductor terminals 187 (lowermost terminal of Fig. 2) and 188, to one end of the winding of the grid contactor relay 122 with the remaining end of this latter relay 122 being in turn connected by a conductor 189 to the conductor terminal 127 and thus through conductor 126 to one of the supply terminals 128.

The novel features of our present invention may be better understood by the operation thereof so it will be assumed an operator desires to

take a radiographic exposure of some portion of the human anatomy utilizing X-rays of a substantially uniform intensity thus requiring a single impulse energization of the X-ray tube free from all sinusoidal influence. The switch 18 is then moved to the left as viewed from Fig. 2. The condensers 43 and 50 having, as hereinbefore mentioned, a total capacity of 1 microfarad thus establishing a fixed ratio relative to their charging circuit, which is governed by the auto-transformer controls at the correct line voltage, accordingly requires only an inspection of a pre-calibrated chart to determine the correct kilovoltage for the particular portion of the patient's anatomy it is desired to radiograph.

The movable arms 16 and 17 are then moved to the requisite kilovoltage in tens and units as indicated by the dials at the control stand. The filament switch 85 is then set for either ultra-rapid or usual speed and the main line switch 5 is closed. If the voltage of the source is normal the pointer of the voltmeter 15 aligns with the single graduation of the dial or if there is any variation the line voltage regulator 14 is adjusted until the pointer does align with the single graduation.

Upon closure of the main line switch 5 the auto-transformer 8 is energized which in turn energizes the low tension heating transformers 86, 87 and 90 for the respective rectifying valves V1, V2, V3, and V4. Likewise the low tension heating transformer 66 for the X-ray tube XR2 is energized from the auto-transformer through the speed controlling switch 85 and the blades 77 and 78 of switch 18 which thus heats the cathode of X-ray tube XR2.

The pilot lights 166 and 167 are immediately lighted, for the purpose of illuminating the meters 15 and 32 as well as the transparent numbered auto-transformer dials (not shown), due to their direct connection to the "control supply" conductor terminals 128. These terminals 128 being connected by the conductors 129 and 130 directly to the appropriate taps of the auto-transformer 8 will, for the sake of simplicity, be hereinafter referred to as the source of supply with opposite instantaneous polarity therebetween being designated "A" and "B" current.

The pilot light 159, which indicates upon the control panel that the system is set for a single impulse or condenser discharge generator, is also illuminated, due to one of its terminals being connected to one of the "control supply" terminals 128 while its other terminal is likewise connected to the other "control supply" terminal 128, by means of the conductor 136, switch blade 135 and terminal 134, and the conductor 158 which extends through the conductor terminal 164 to the armatures 163 and 160 of the respective relays 149 and 152 as well as the lamp 159.

Also closure of the main line switch causes the immediate energization of the high tension transformer 93 as the circuit for the primary winding 125 is completed from the source of supply 128, through conductor 126 and terminal 127, to the winding 125 and thence back to the other supply terminal 128, through conductor 132, switch terminal 134 and arm 135, and conductor 136. This in turn causes the associated secondary windings to heat the cathodes of the valve tubes 100, 105, and 106 and to generate the auxiliary potential for the grid circuit of trigger tube 56 as hereinbefore described.

Moreover, simultaneously with energization of the transformer 93, the grid contactor relay 122

is energized thus allowing the immediate application of a negative polarity to the grid. This circuit is completed from the source 128, by the conductor 126, terminal 127 and conductor 189 to the winding of relay 122 and thence, through conductor 195, terminals 188 and 187, stationary contact terminal 186 of relay 149, armature 163 thereof, to conductor 158 which in turn is connected to the remaining supply terminal 128 by the switch terminal 134 and arm 135 of switch 18, as well as the conductor 136.

It has been heretofore mentioned that a stereoscopic mechanism for the taking of two radiographic exposures in rapid succession but from different angles may be utilized if desired. As is usual in employing such apparatus one exposure is made after which both the tube and cassette tray housing the sensitized film are shifted and the exposure is repeated. The actual shifting of the cassette tray being accomplished by mechanical means the operation of which is electrically initiated we have merely shown diagrammatically such mechanism under the designation "stereo shift mech" in Fig. 3. Also in order to give a visual indication to the operator at the control board whether the first or second stereoscopic exposure has been made we provide the indicating pilot lights 179 and 146 which are marked "1st" and "2st" respectively.

Under the conditions assumed and upon closure of the main line switch 5 the pilot 179 or "1st" will now be illuminated as one terminal thereof is connected directly to the "A" current terminal 128 while "B" current is supplied by the conductor 180 and stationary contact terminal 182 of relay 162, which is engaged by the armature 160 connected to conductor 158 now carrying "B" current from the source 128 in the manner previously explained.

Energization of the "stereo shift" mechanism does not at this time occur, despite the fact that "A" current from the source 128 is supplied thereto through the contacts 142 and 144 of the control switch 137, as "B" current from the source is interrupted by the contactors 155 and 170.

All conditions for the taking of the exposure having been now fulfilled the operator depresses the push button switch 137 causing downward movement thereof. Initial movement of this switch 137 interrupts the engagement of the contact members 142 and 144 and, upon further movement causes the contact member 142 to engage the stationary contact member 147 prior to the engagement of the contact members carried by the insulated block 153 with those affixed to the insulating block 168. The contact member 142, which is directly connected to the "A" current terminal 128, upon engaging the contact member 147 completes a circuit to the condenser short circuiting relays 60 and 64 by means of the conductor 148 through the conductor terminals 150 and 152 to one end of the respective relay windings and "B" current is supplied thereto from the source 128 through the conductor 132 which is connected also to one end of the primary winding 125. This accordingly disconnects the output circuit of the condensers 43 and 50 from ground through the leakage resistances 62 and 65.

Further downward movement of the switch button 137 then causes the respective engagement of contact members 154, 163; 155, 170; 156, 172 and 157, 173 while contact member 142 is still maintained in engagement with the member 75

147 due to the slight spring action of the latter.

The contactor 154, being connected directly to the "B" current terminal 128 by the conductor 165, upon engagement with contact member 169, completes a circuit to the winding of relay 31 through conductor 174 with the other end of this relay winding receiving "A" current direct from the supply terminal 128 through the conductor 175. The armature 30 of this relay 31 is accordingly attracted thus first establishing an engagement with the contactor 33 and then immediately causing the engagement of the contactor 33 with the contactor 35.

Closure of the respective contactors of this relay immediately causes energization of the high tension transformer 25, by completing the normally open circuit previously described for the primary winding 24 thereof, with the resistance 34 being momentarily connected in series in the circuit to absorb the initial surge of current but almost immediately short circuited by the engagement of contactor 33 with contactor 35. The secondary winding 37 then charges the respective condensers 43 and 50 with unidirectional energy as is well understood until they become completely charged. The operator accordingly retains the push button switch 137 in its downmost position until the condensers have accumulated their charge which is indicated by the modified form of ammeter 32 connected in electrical series with the primary winding 24. When this latter winding is initially energized the pointer of this meter, the dial of which may be calibrated in terms of milliamperes, is sharply deflected but in a few seconds falls to zero thus indicating to the operator that the condensers are then fully charged and the push button is ready to be released.

The contact member 155, which is now supplied with "B" current from the source 128 through the conductor 158, in engaging the contact member 170 completes a circuit, through the conductor 177 and stationary contact member 178, to the winding of relay 162 and also supplies "B" current to the "stereo shift" mechanism but the latter is unenergized as "A" current thereto is now interrupted by the disengagement of the respective contact members 142 and 144. However, the relay 162 becomes energized due to its other end being connected by the conductor 143 directly to the "A" current supply terminal and its armature 160 is thus attracted and engages the stationary contact terminal 178 to form a self holding coil by supplying "B" current from the conductor 158 to the winding of the relay 162 independent of the circuit formed by the engagement of the contact terminals 155 and 170. This movement of the armature 160 likewise causes disengagement thereof with the stationary contact terminal 182 of the relay 150 and thus interrupts the circuit to the pilot light 179 for the first "stereo" picture.

Engagement of the respective contact members 156 and 172 completes a self holding circuit for the winding of relay 149, due to "A" current being supplied thereto by the conductor 143, contactors 142 and 147, and conductor 148, while "B" current is supplied from the conductor 159 (now still carrying "B" current as previously explained), through the contact members 156 and 172, and conductor 183. This accordingly causes attraction of the armature 163 of the relay 149 with the establishment of a contact with the terminal 184 so that "B" current is then supplied directly

to the relay winding from the conductor 158 independent of the engagement of the contact members 156 and 172.

Movement of the armature 163 thus causes a disengagement thereof with the stationary contact terminal 186, which would tend to interrupt the circuit established thereby through a portion of the conductor 185 and terminals 187 and 188 to the grid contactor relay 122, were it not for the fact that this circuit is now completed through the remaining contact terminals 157 and 173. The contact member 157 is supplied with "B" current by the conductor 158 and accordingly reestablishes the circuit to the grid contactor relay 122, even upon movement of the armature, through that portion of the conductor 185 extending from the switch contact member 173 to the relay contact member 186 thus maintaining the grid relay energized.

The charging indicating meter 32 having now shown the operator that the condensers are fully charged he then releases the pressure on the push button 137, which will then be retracted to its original position by the potential energy of the springs 138. This accordingly causes interruption of the circuit to the relay 31 which will automatically open to its normal position through the action of a biasing spring and cause deenergization of the high tension transformer 25 by interrupting the circuit for the primary winding 24. At the same time the contacts 154 and 169 become disengaged to interrupt the circuit to the winding of relay 31, the contact members 157 and 173 are likewise disengaged to cause an interruption in the circuit to the winding of the grid contactor relay 122, but as this latter relay closes by gravitation and has a farther distance to travel before establishing a contact with its associated terminals, than does the relay 31 before causing deenergization of the transformer 25, the latter relay naturally functions first thus preventing any sinusoidal influence from the alternating current being impressed upon the X-ray tube XR2.

Upon closure of the relay 122 a positive polarity is impressed upon the grid of the trigger tube 56 in the manner previously described thus rendering the latter conductive which causes the condensers 43 and 50 to discharge in series through the X-ray tube XR2 with an attendant exposure. The interruption of the engagement of the respective contact members 155, 170 and 156, 172 by the upward movement of the push button switch 137 has no effect upon the system at this time for the aforementioned reason that a self holding circuit has been established to the windings of the respective relays 149 and 162 by the armatures thereof.

However, further upward movement of the push button 137 will interrupt the engagement of the contact members 142 and 147. This accordingly deenergizes the winding of relay 149 and the windings of the condenser short circuiting relays 60 and 64, as "A" current was supplied thereto through these contact members 142 and 147 as before noted. The relays 60 and 64 will thus fall and bridge their associated contact members to complete the output circuit for the condensers 43 and 50 to cause any remaining energy stored therein to discharge to ground through the respective leakage resistances 62 and 65, thus obviating the possibility of serious shocks resulting to patient or operator should they accidentally contact any part of the high tension portion of our system when it is not actually in use.

It should also be noted that upon deenergization of the relay 143 its armature 163 is automatically retracted to its normal open position in engagement with the stationary contact terminal 126 which will again energize the grid contactor relay 122 by supplying "B" current thereto in the manner previously described.

This again causes the auxiliary source to impress a high negative polarity upon the grid of the trigger tube 56 in readiness for another exposure although no energy is at this instant flowing through this tube as the primary winding 24 of the high tension transformer 25 is not only interrupted at the contactors 30, 33 and 35 of relay 31, but the condensers 43 and 53 are now short circuited to ground.

When the switch 137 completes its movement to its normal or uppermost position contact will again be established between the contact members 142 and 144 which will now complete a circuit to the "stereo shift" mechanism to cause shifting of the cassette tray encasing the sensitized films as well as change the angle between the X-ray tube and patient as is well understood with such mechanism. This circuit may be traced from conductor 150 (still carrying "B" current from the supply terminal 128 as before explained) through the armature 160 to the terminal 170 and one end of the relay winding, through conductor 177 to the "stereo shift" mechanism and thence back, through conductor 145, contact members 144 and 142, and conductor 143 to the "A" current supply terminal 128 by means of the conductor 143.

One exposure having been previously made when the X-ray tube was previously energized and upon energization of this "stereo shift" mechanism the second film is moved into position for an exposure. Moreover, the fact that the second exposure is in position is now indicated to the operator at the control stand by the pilot light 146 which becomes illuminated simultaneously with the engagement of the contact members 142 and 144 with attendant shifting of the sensitized films as "B" current is supplied thereto through the conductor 177 and "A" current by the contact members 142, 144 and the conductor 145.

The entire system is thus in position for another exposure and upon initial depression of the push button switch 137 with disengagement of the contact members 142 and 144 the pilot light 146 becomes extinguished and the second exposure is made in the identical manner as just stated.

It should be noted, however, that even after completion of the second exposure the winding of relay 162 is still energized due to the self holding circuit established by its armature 160. But as both exposures have now been completed and the operator is ready to remove the films he naturally deenergizes the entire apparatus by opening the main line switch 5 which causes deenergization of the relay 160, or should he desire to convert the apparatus to a pulsating generator, movement of the switch 13 to the right as shown in Fig. 2 will also interrupt the circuit with attendant deenergization of the relay 160.

Having thus described our novel system when utilized as a single impulse or condenser discharge generator we will now describe the same when it is converted, for certain other classes of work, to a pulsating X-ray generator. It should also be stated that although we have shown as a preferred embodiment of our invention the use of

separate X-ray tubes for each operation it is to be understood that a single X-ray tube may be utilized and throughout the majority of our appended claims only one X-ray generating tube will be referred to.

We have found that with X-ray tubes as at present constructed it is preferable to employ a line focus X-ray tube in junction with condenser discharge energization thereof, to avoid deleterious results to the target because of the extremely large quantity of energy passing through the tube in such an exceptionally short period of time, and also to prevent loss of definition to the resulting radiographic film.

On the other hand when utilizing our system as a pulsating generator the usual commercial type of radiographic tube may be employed. Should it be preferred to utilize but a single tube for either type of energization without sacrificing definition it would be more desirable to utilize either a double focus X-ray tube or one having a rotating anode or target. For the sake of simplicity we will accordingly describe our system as utilizing the usual type of radiographic X-ray tube XR1 for pulsating energization.

The normally operable switch 13 is moved to the right, as shown in Fig. 2, causing the blades 47 and 69 thereof to disengage the switch terminals 48 and 70 thus interrupting the cathode heating source for the X-ray tube XR2 as well as the conductor 49 which is common to one side of the condensers 50 and the high tension conductor 53, and causes these blades 47 and 69 to engage another pair of switch terminals 192 and 193, respectively. The terminals 192 and 193 are connected by conductors 194 and 195, respectively, to the cathode of an X-ray tube XR1 thus supplying heating current from the secondary winding 67 of the transformer 66, as well as high potential energy from one output terminal of the high tension rectified source which is connected directly to the conductor 46 extending from the winding 67 to the switch blade 47.

The switch blade 39, which is connected to the other output terminal of the high tension rectified source, also disengages the switch terminal 40 thus interrupting the charging circuit to the condensers 43, and this blade will engage a further switch terminal 196 which is connected to the anode of the X-ray tube XR1 by means of a conductor 197.

Consequently upon energization of the high tension transformer 25 as hereafter explained, the high rectified pulsating potential generated thereby will be supplied directly to the X-ray tube. At the same time the switch blade 135 of switch 13 will disengage the terminal 134, interrupting the supply of energy from the "B" supply terminal 128 to the primary winding 125 of transformer 93 as well as to one end of each relay winding 60 and 64, and the blade 135 engages another switch terminal 198. A conductor 199 in turn connects this latter switch terminal 198, through a conductor terminal 200, to one terminal of the pilot light 176. As the conductor 199 is supplied with "B" current from the supply terminal 128 through conductor 136 and the blade 135, this pilot light is immediately illuminated to give a visual indication at the control board that the system is set as a pulsating generator due to the circuit to this lamp being completed to the "A" current terminal 128 through the conductor 175.

The switch blades 77 and 78, which are directly connected to the primary winding 74 of

low tension heating transformer 66, disengage the switch terminals 79 and 80, respectively, to interrupt the supply of energy thereto from the auto-transformer 8 through the two position speed switch 85, and establish an engagement with a pair of switch terminals 202 and 203. The switch terminal 202 is in turn connected, by means of a conductor 204 through a conductor terminal 205 and variable resistance 206 upon the panel of the control stand, to an appropriate tap of the auto-transformer 8. The terminal 203 is likewise connected, by means of a conductor 207 and conductor terminal 208, to the auto-transformer 8 for the purpose of enabling energization of the heating transformer 66 with the series connected rheostat 206 governing the quantity of current supplied thereto.

The switch blade 22, which is connected directly to one end of the primary winding 24 of high tension transformer 25 and to the segmental bar 19 of the adjustable arm 17, will now engage a switch terminal 209; connected by means of a conductor 210 through a conductor terminal AA1, to a further segmental bar 212, positioned to be engaged by the adjustable arm 17 to allow a slightly higher voltage to be supplied to the primary winding 24, than when the arm is in engagement with the segmental bar 19. The switch blade 27, which formerly engaged the switch terminal 28 connected to the charging indicator 32, will now engage a switch terminal 213 which is connected, by means of a conductor 214 through a conductor terminal A1, to the conductor 29 ahead of the indicating meter 32 to thus short circuit this meter so that it is no longer in series with the energizing circuit for the primary winding 24. Again this latter circuit is not completed as yet due to its being interrupted at the contactors 30, 33, and 35, of relay 31.

The operation of our system as a pulsating X-ray generator is as follows: the main line switch 5 is first closed which energizes the auto-transformer 8 with attendant energization of the cathode heating transformers 66, 86, 87 and 90 as well as the illumination of the pilot lights 166, 167, which are directly connected to the supply terminal 128, and the pilot light 176. The rheostat 206 is then set to give the desired milliamperage of current and the control knobs 16 and 17 set to the kilovoltage required as noted upon the chart for the particular portion of the anatomy to be radiographed. The system is, therefore, in readiness for the exposure which is made by the operator depressing the push button switch 137.

This again closes the contact members 154 and 169 and energizes the winding of relay 31 thus causing closure of the respective contactors 30, 33 and 35 with attendant energization of primary winding 24 and X-ray tube XR1, as long as the operator retains the push button 137 in its downmost position. Immediately upon release of this push button the relay 31 is deenergized and opens its contactors thus deenergizing the X-ray tube XR1.

Moreover, no other circuits which were completed in the manner previously described by movement of the push button switch 137 are at this time affected. This is due to the conductor 158, which carried "B" current from the supply terminal 128 when the switch blade 135 was in contact with the terminal 134, being now interrupted by this switch blade. Accordingly none of the former mentioned circuits are now connected to the "B" current supply terminal in any

other manner except that just noted. It should be mentioned, however, that although in our system as shown we have made no provision for the utilization of a stereoscopic mechanism therewith when the system is operable as a pulsating generator the same may be readily adapted thereto. In the majority of instances when a stereoscopic examination is desired the more rapid exposures obtained with our system operating as a condenser discharge or impulse generator appear to be preferable thus rendering the provision of such mechanism unnecessary for pulsating X-ray generation.

The energization of the X-ray tube by pulsating energy being dependent upon the operator maintaining the push button 137 in the depressed position thus renders timing somewhat uncertain. In order to obviate this uncertainty a timing device (not shown, but indicated in Fig. 3 "to timing device") may be connected to our system by a pair of conductors 215 and 216, which extend to the respective conductors 199 and 174, thus providing a switch for causing energization of the relay 31 for preselected periods of time, independent of the switch 137.

It thus becomes obvious to those skilled in the art that we have provided an X-ray system which is operable either as a single impulse or pulsating X-ray generator as desired and may be immediately converted from one type of generator to the other. When the system is utilized as a single impulse or condenser discharge generator the quantum of energy for the X-ray tube may be definitely determined before the exposure and this energy precisely delivered to the X-ray tube. Also when the system is not actually in use and immediately after its use, it is rendered shock-proof thus eliminating the hazard of shocks resulting from the accidental contact of the various parts by an operator or patient. Moreover, due to the manner of controlling the discharge of the condensers and the slight retardation in the speed of impressing a positive polarity upon the grid of the trigger tube a steep wave front in the initial surge of energy through the X-ray tube is prohibited thus preventing deleterious results to X-ray or trigger tubes.

The entire operation of our system is remotely controlled from a control stand which gives an accurate visual indication to the operator of the entire condition of the system at each moment during its operation. Also the entire operation of the system is in response to a single actuating switch which causes preselected operation of various parts of our system in a precise and predetermined sequence thus rendering the operation of the system as a whole very simple so that an exceptionally skilled operator is not required.

Having thus described our invention we do not desire to be limited thereto as various other modifications thereof may be made without departing from the spirit and scope of the appended claims.

What is claimed:

1. In an X-ray system, the combination with a pair of X-ray tubes, of a high potential source of rectified alternating current electrical energy, energy storage means adapted to be connected to said source for accumulating a charge therein, means interposed between one of said X-ray tubes and said energy storage means and operative to cause energization of said last mentioned X-ray tube by a single impulse of energy from said energy storage means, and means operative in one position to disconnect the other of said X-ray

tubes from said source and to connect said source, said energy storage means, said first mentioned means and said last mentioned X-ray tube, in circuit to operate as a single impulse X-ray generator; and said last mentioned means being operative in another position to disconnect said energy storage means and said last mentioned X-ray tube from said source and for rendering said first mentioned means ineffective, and to connect the other of said X-ray tubes to said source in order to energize the same by pulsating energy derived therefrom.

2. In an X-ray system the combination with a pair of X-ray tubes of a high potential source of rectified alternating current electrical energy, energy storage means adapted to be connected to said source for accumulating a charge therein, means connected to one of said X-ray tubes and said energy storage means for causing discharge of said energy storage means through said last mentioned X-ray tube, and means operable in one position to disconnect the other of said X-ray tubes from said source and to connect said source, said energy storage means, said last mentioned X-ray tube, and said means for causing discharge of said energy storage means, in a circuit to cause said system to operate as an impulse X-ray generator; and said last mentioned means being operable in another position to disconnect said energy storage means, said last mentioned X-ray tube and said means for causing discharge thereof from said source, and to connect the other of said X-ray tubes to said source in order to energize the same with pulsating electrical energy derived therefrom.

3. In an X-ray system the combination of a high potential source of rectified alternating current electrical energy, energy storage means adapted to be connected to said source for energization thereby, an X-ray tube energizable by the discharge of said energy storage means, a second X-ray tube adapted to be energized by said high potential source, means interposed between said first mentioned X-ray tube and said energy storage means operable to cause discharge of the latter through said X-ray tube, and means operable in one position to disconnect said second X-ray tube from said source and to connect said energy storage means to said source for energization thereby and said X-ray tube to said energy storage means to cause said system to operate as an impulse X-ray generator, and said last mentioned means being operable in another position to disconnect said energy storage means and said X-ray tube from said source and to connect said second mentioned X-ray tube directly thereto to cause said system to operate as a pulsating X-ray generator.

4. In an X-ray system the combination of a high potential source of electrical energy, energy storage means adapted to be connected to said source for energization thereby, a plurality of rectifiers interposed between said high potential source and said energy storage means for causing electrical energy of one sign only to be stored in said energy storage means by said source, an X-ray tube adapted to be energized by said energy storage means upon the discharge thereof, means operable to cause the discharge of said energy storage means through said X-ray tube, a second X-ray tube adapted to be connected to said high potential source and said rectifiers for energization by electrical energy of one sign only from said high potential source, and means operable in one position to disconnect

said second X-ray tube from said source and to connect said energy storage means to said source of electrical energy and said first-mentioned X-ray tube to said energy storage means, and operable in an other position to disconnect said energy storage means from said source and said X-ray tube from said energy storage means and to connect said second mentioned X-ray tube to said high potential source and said rectifiers for energization by energy of one sign only from said source.

5. In an X-ray system the combination of a high potential source of electrical energy, energy storage means adapted to be connected to said source for energization thereby, a plurality of rectifiers interposed between said high potential source and said energy storage means for causing electrical energy of one sign only to be stored in said energy storage means by said source, an X-ray tube adapted to be energized by said energy storage means upon the discharge thereof, means operable to electrically connect said energy storage means to said X-ray tube to cause energization thereof by the discharge of said energy storage means, a second X-ray tube adapted to be connected to said high potential source and said rectifiers for energization by electrical energy of one sign only from said high potential source, and means operable in one position to disconnect said second X-ray tube from said source and to connect said energy storage means to said high potential source to cause energization of said first mentioned X-ray tube by the discharge of said energy storage means upon operation of said means electrically connecting said X-ray tube to said energy storage means, and said last mentioned means being operable in another position to disconnect said energy storage means from said high potential source upon connection of said second X-ray tube thereto.

6. In an X-ray system the combination of a high potential transformer provided with a primary and a secondary winding, a source of electrical energy adapted to be connected to the primary winding of said transformer for energizing the same, a condenser adapted to be connected to the secondary winding of said transformer, a plurality of rectifiers connected to said secondary winding and said condenser for causing electrical energy of one sign only to be stored in said condenser by said high tension transformer, an X-ray tube adapted to be energized by the discharge of said condenser, means interposed between said X-ray tube and said condenser and operative to cause energization of said X-ray tube by a single impulse of energy from said condenser, a second X-ray tube adapted to be connected to the secondary winding of said high tension transformer and said rectifiers for energization by electrical energy of one sign only from said transformer, and a switch operable in one position to connect said condenser to said secondary winding and rectifiers and operable in another position to disconnect said condenser from said rectifiers and secondary winding and to connect said second mentioned X-ray tube to the secondary winding of said high tension transformer and said rectifiers for energization by pulsating energy of one sign only from said transformer.

7. In an X-ray system, the combination of a high potential source adapted to generate a precise preselectable quantity of rectified alternating current electrical energy, means connected to said high potential source having a predetermined ca-

capacity for accumulating a high potential charge of a definite quantity therein of a fixed ratio relative to the potential of said high potential source, an X-ray tube adapted to be energized by the charge accumulated in said means, means connected to said X-ray tube and to said first mentioned means adapted upon operation thereof to cause said accumulated charge to be supplied to said X-ray tube, and means electrically associated with said high potential source and said last mentioned means, and operable to cause the sequent deenergization of said high potential source and operation of said last mentioned means with attendant energization of said X-ray tube free of the imposition of a sinusoidal wave form from said high potential source.

8. In an X-ray system, the combination of high potential rectified alternating current generating means, adjustable means adapted to be connected to said high potential generating means and operable to cause the same to generate a precise preselectable quantity of electrical energy in any position of said adjustable means, means connected to said high potential generating means having a predetermined capacity for accumulating a high potential charge of a definite quantity therein of a fixed ratio relative to the potential of said high potential source, an X-ray tube adapted to be energized by the charge accumulated in said last mentioned means, means connected to said X-ray tube and said last mentioned means and operable to control the energization of said X-ray tube by said last mentioned means, and means electrically associated with said last mentioned means and said high potential generating means, and operable to cause the sequent deenergization of said generating means and operation of said last mentioned means with attendant energization of said X-ray tube free of the imposition of a sinusoidal wave form from said generating means.

9. In an X-ray system, the combination with energy storage means, of generating means adapted upon energization thereof to store an electrical charge of high potential and current in said energy storage means, a source of electrical energy for energizing said generating means, a plurality of rectifiers connected to said generating means and said energy storage means to cause energy of one sign only to be stored in the latter upon energization of said generating means, an X-ray tube adapted to be connected to said energy storage means and energizable by the discharge thereof, means connected with said energy storage means and said X-ray tube operable to control the discharge of said energy storage means through said X-ray tube, means normally connecting said energy storage means to ground to render said system shockproof when not in actual operation, and means operable to cause said energy storage means to be disconnected from ground prior to energization of said generating means by said source of electrical energy.

10. In an X-ray system, the combination with energy storage means, of generating means adapted upon energization thereof to store an electrical charge of high potential and current in said energy storage means, a source of electrical energy for energizing said generating means, a plurality of rectifiers connected to said generating means and said energy storage means to cause energy of one sign only to be stored in the latter upon energization of said generating means, an X-ray tube adapted to be connected to said ener-

gy storage means and energizable by the discharge thereof, means connected with said energy storage means and said X-ray tube operable to control the discharge of said energy storage means through said X-ray tube, means normally connecting said energy storage means to ground to render said system shockproof when not in actual operation, and means operable to cause the sequent disconnection of said energy storage means from ground and energization of said generating means by said source of electrical energy.

11. In an X-ray system, the combination with energy storage means, of generating means adapted upon energization thereof to store an electrical charge of high potential and current in said energy storage means, a source of electrical energy for energizing said generating means, a plurality of rectifiers connected to said generating means and said energy storage means to cause energy of one sign only to be stored in the latter upon energization of said generating means, an X-ray tube adapted to be connected to said energy storage means and energizable by the discharge thereof, means connected with said energy storage means and said X-ray tube operable to control the discharge of said energy storage means through said X-ray tube, means normally connecting said energy storage means to ground, and means operable to successively cause disconnection of said energy storage means from ground, energization of said generating means by said source of electrical energy and consequently the charging of said energy storage means by said generating means, and operation of said discharge device in order to cause said energy storage means to discharge through said X-ray tube.

12. In an X-ray system, the combination with a condenser of relatively large capacity of a high tension transformer, a source of electrical energy for energizing said high tension transformer, a plurality of rectifiers connected to said high tension transformer and said condenser to cause energy of one sign only to be stored in the latter upon energization of said high tension transformer, an X-ray tube adapted to be connected to said condenser and energizable by the discharge thereof, means connected with said condenser and said X-ray tube operable to control the discharge of said condenser through said X-ray tube, a relay normally operative to connect said condenser to ground to render said system shockproof when not in actual operation, and means operable to successively cause energization of said relay to disconnect said condenser from ground, energization of said high tension transformer by said source of electrical energy, and operation of said first mentioned means with attendant energization of said X-ray tube by the discharge of said condenser.

13. In an X-ray system the combination with a high potential circuit including energy storage means, means for supplying said energy storage means with electrical energy of one sign only, an X-ray tube adapted to be connected to said energy storage means and energizable by the discharge thereof, and a thermionic discharge device connected to said energy storage means and said X-ray tube for controlling the discharge of said energy storage means through said X-ray tube; of an auxiliary circuit of relatively low potential operable to cause operation of said discharge device, remotely operable means associated with said energy storage means to connect the same to ground to render said system shockproof when

not actually in operation, remotely operable means associated with said first mentioned means for rendering the same effective to supply energy to said energy storage means, remotely operable means associated with said auxiliary circuit to render the same effective to cause operation of said discharge device, a plurality of partially completed low tension control circuits each of which includes one of said remotely operable means, and means adapted to be included in each of said control circuits and operable to complete each of said control circuits with attendant successive actuation of each of said remotely operable means.

14. In an X-ray system, the combination of a high potential source of rectified alternating current electrical energy, energy storage means adapted to be connected to said high potential source for accumulating a charge therein, an X-ray tube, a thermionic discharge device connected to said X-ray tube and to said energy storage means adapted upon operation thereof to cause energization of said X-ray tube by the charge accumulated in said energy storage means, a second X-ray tube adapted to be energized by said high potential source, means operable in one position to connect said energy storage means in said high potential source and operable in another position to disconnect said energy storage means and to connect said second mentioned X-ray tube to said high potential source for energization thereby independent of said energy storage means, a control stand, visual indicating means disposed upon said control stand and operable by said two position means to indicate whether said first mentioned X-ray tube is connected to said energy storage means or said second mentioned X-ray tube is connected directly to said high potential source, a plurality of control circuits adapted upon completion thereof to sequentially cause energization of said high potential source and the accumulation of a charge in said energy storage means, the deenergization of said high potential source, and the operation of said thermionic discharge device with attendant energization of said X-ray tube by the charge accumulated in said energy storage means; and means disposed upon said control stand and operable to complete each of said control circuits in their predetermined sequence.

15. In an X-ray system, the combination of a high potential source of rectified alternating current electrical energy, energy storage means adapted to be connected to said high potential source for accumulating a charge therein, an X-ray tube, a thermionic discharge device connected to said X-ray tube and to said energy storage means adapted upon operation thereof to cause energization of said X-ray tube by the charge accumulated in said energy storage means, a second X-ray tube adapted to be energized by said high potential source, means operable in one position to connect said energy storage means to said high potential source and operable in another position to disconnect said energy storage means and to connect said second mentioned X-ray tube to said high potential source for energization thereby independent of said energy storage means, a control stand remotely disposed relative to said high tension source and both of said X-ray tubes, a stereoscopic mechanism for exposing a plurality of sensitized films in rapid succession in the field of X-radiation from either of said X-ray tubes, visual indicating means disposed upon said control stand operable by

said two position means to indicate when said first mentioned X-ray tube is connected to said energy storage means or said second mentioned X-ray tube connected directly to said high potential source, visual indicating means disposed upon said control stand for indicating the particular sensitized films disposed at any moment to the field of X-radiation from said X-ray tube, a plurality of control circuits adapted upon completion thereof to sequentially cause energization of said high potential source and the accumulation of a charge in said energy storage means, the deenergization of said high potential source, the operation of said thermionic discharge device with attendant energization of said X-ray tube by the charge accumulated in said energy storage means, and operation of said stereoscopic mechanism to shift the exposed sensitized film out of the field of X-radiation and the other of said sensitized films into position for an exposure; and means disposed upon said control stand and operable to complete all of said control circuits in a predetermined sequence to cause the respective sequential operation.

16. In an X-ray system the combination with a high potential circuit comprising an X-ray tube electrically connected to a high capacity condenser for energization thereby, a high tension transformer connected to said condenser adapted upon energization thereof to charge said condenser, a plurality of rectifiers connected in the circuit with said high tension transformer and said condenser to cause the latter to be charged with electrical energy of one sign only by said high tension transformer, a thermionic discharge device connected in series with said X-ray tube and said condenser provided with a control electrode operable to cause and prevent the discharge of said condenser through said X-ray tube, means normally connecting said condenser to ground to render said system shockproof when not actually in operation; of an auxiliary circuit including the control electrode of said discharge device and operative to impress a negative or a positive potential thereupon, means associated with said auxiliary circuit and operable to cause operation of said auxiliary circuit to render the control electrode of said discharge device effective to cause and prevent the discharge of said condenser through said X-ray tube, means operable to connect said high tension transformer to a suitable source of electrical energy for energization thereby, a control circuit for actuating said condenser grounding means, a control circuit for causing operation of said means to connect said high tension transformer to a suitable source of electrical energy, a control circuit for actuating said means associated with said auxiliary circuit and operable to cause the same to render said auxiliary circuit effective, and means operable to cause each of said control circuits to become effective in a predetermined sequence.

17. In an X-ray system the combination of means for storing an electrical charge of high potential, an X-ray tube adapted to be connected to said means for energization thereby, a thermionic discharge device provided with an anode and a cathode connected to said means and said X-ray tube, respectively, said discharge device being further provided with a control electrode to cause and prevent the flow of energy between the anode and cathode thereof and consequently from said means to said X-ray tube, an auxiliary source of electrical energy connected to the con-

5 trol electrode of said discharge device normally
operative to impress a negative potential there-
upon to prevent the discharge of said means
through said X-ray tube, automatic means asso-
10 ciated with said auxiliary source of energy oper-
able to cause said auxiliary source to reverse the
polarity of the potential impressed upon said con-
trol electrode and cause said means to discharge
15 through said X-ray tube, and means connected
with said auxiliary source of electrical energy to
cause the gradual reversal in the polarity of the
potential impressed thereby upon said control
electrode in a fractional part of a second in re-
sponse to the operation of said automatic means
to cause a corresponding gradual rise in the dis-
charge of energy from said means through said
X-ray tube.

18. In an X-ray system the combination of
means for storing an electrical charge of high
20 potential, an X-ray tube adapted to be connected
to said means for energization thereby, a ther-
mionic discharge device in series with said X-ray
tube and said means operable to cause and pre-
vent the flow of energy from said means to said
25 X-ray tube, an auxiliary source of electrical en-
ergy connected with said discharge device nor-
mally operative to cause said discharge device to
positively prevent the flow of energy from said
means to said X-ray tube, a switch operable to
30 cause said auxiliary source to reverse the oper-
ation of said discharge device and cause the en-
ergy of said means to discharge through said
X-ray tube, and means connected with said aux-
iliary source of electrical energy to cause the
35 gradual reversal in operation of said discharge
device in a fractional part of a second in response
to the operation of said switch to prevent a sud-
den rush of energy from said means to said X-
ray tube from deleteriously affecting said X-
40 ray tube and said discharge device.

19. In an X-ray system the combination of
means for storing an electrical charge of high
potential, an X-ray tube adapted to be connected
to said means for energization thereby, a ther-
45 mionic discharge device provided with an anode
and a cathode connected to said means and said
X-ray tube, respectively, said discharge device be-
ing further provided with a control electrode to
cause and prevent the flow of energy between the
50 anode and cathode thereof and consequently from
said means to said X-ray tube, an auxiliary source
of electrical energy connected to the control elec-
trode of said discharge device normally operative
to impress a negative potential thereupon to pre-
55 vent the discharge of said means through said
X-ray tube, a relay associated with said auxiliary
source of energy operable to cause said auxiliary
source to reverse the polarity of the potential im-
pressed upon said control electrode and cause
60 said means to discharge through said X-ray tube,
and a resistance element connected with said
auxiliary source of electrical energy to cause the
gradual reversal in the polarity of the potential
impressed thereby upon said control electrode in
65 a fractional part of a second in response to the
operation of said relay to cause a corresponding
gradual rise in the discharge from said means
through said X-ray tube.

20. In an X-ray system, the combination of a
70 high potential source of electrical energy includ-
ing a condenser, an X-ray tube adapted to be en-
ergized by said source, means interposed between
said source and said X-ray tube for controlling
the energization of the latter, means normally
75 connecting said condenser to ground to render

said system shock-proof, and means operable to
render said last mentioned means ineffective by
disconnecting said condenser from ground and
for causing operation of said first mentioned
means with attendant energization of said X-ray
5 tube by said high potential source.

21. In an X-ray system, the combination with
generating means including a condenser and
adapted upon energization thereof to accumulate
an electrical charge of high potential in said
10 condenser, of a source of electrical energy for
energizing said generating means, an X-ray tube
adapted to be connected to said generating means
for energization thereby, means connected to said
generating means and said X-ray tube and oper-
15 able to control the energization of the latter by
said generating means, means normally connect-
ing said condenser to ground to render said sys-
tem shock-proof, and means operable to render
said last mentioned means ineffective to ground
20 said system and to connect said source of electri-
cal energy to said generating means.

22. In an X-ray system, the combination with
generating means including a condenser and
adapted upon energization thereof to accumu-
25 late an electrical charge of high potential in
said condenser, of a source of electrical energy
for energizing said generating means, an X-ray
tube adapted to be energized by said generating
means, means connected to said generating
30 means and said X-ray tube and operable to con-
trol energization of the latter, means normally
connecting said condenser to ground to render
said system shockproof following energization
of said X-ray tube, and means operable to render
35 said last mentioned means ineffective to ground
said system and to connect said source of electri-
cal energy to said generating means and to
cause operation of said first mentioned means
with attendant energization of said X-ray tube
40 by said generating means.

23. In an X-ray system, the combination of
generating means including a condenser and
adapted to accumulate an electrical charge of
45 high potential in said condenser, a source of
alternating current electrical energy for ener-
gizing said generating means, an X-ray tube
adapted to be connected to said condenser for
energization by the discharge therefrom, means
connected to said condenser and said X-ray tube
50 and operable to control the energization of the
latter by the discharge from said condenser,
means normally connecting said condenser to
ground to dissipate any residual energy accumu-
lated therein following energization of said X-
55 ray tube for a predetermined period of time,
and means operable to render said last men-
tioned means ineffective to ground said system
together with operation of said first mentioned
means and disconnection with said source from
60 said generating means to prevent a sinusoidal
ripple being imposed upon the X-ray tube exci-
tation energy from said condenser.

24. In an X-ray system, the combination with
an X-ray tube and a source of high potential
65 electrical energy therefor, of a control stand,
adjustable means carried by said control stand
and connected to said high potential source for
minutely controlling the energy supplied to the
latter, and a pair of control knobs carried by
70 said control stand provided with dials having
indicia thereon indicative of kilovoltage in terms
of units and tens, respectively, and operable to
regulate said adjustable means to preselect the
quantity of electrical energy in terms of kilovolt-
75

age supplied by said high potential source to said X-ray tube.

25. In an X-ray system, the combination with an X-ray tube and a source of high potential
5 electrical energy therefor, of a control stand, adjustable means carried by said control stand and connected to said high potential source for minutely controlling the energy supplied to the latter, a pair of control knobs carried by said
10 control stand provided with dials having indicia thereon indicative of kilovoltage in terms of units and tens, respectively, and operable to regulate said adjustable means to a preselected setting corresponding to the kilovoltage supplied
15 by said high potential source to said X-ray tube, and illuminating means carried by said control stand for rendering the dials carried by said control knobs readily visible to an operator.

26. In an X-ray system the combination with

an X-ray tube and a source of high potential electrical energy therefor including a transformer, of a control stand, an auto-transformer carried by said control stand and connected to said transformer for minutely controlling the
5 energy supplied thereto, a pair of control knobs carried by said control stand provided with dials rotatable with said knobs and having indicia thereon indicative of kilovoltage in terms of
10 units and tens, respectively, and said control knobs being operable to regulate said autotransformer to a preselected setting corresponding to the kilovoltage supplied by said high potential source to said X-ray tube, and illuminating
15 means carried by said control stand for rendering the dials carried by said control knobs readily visible to an operator.

MONTFORD MORRISON.
ALFRED SIMON.