April 13, 1943. J. M. CONSTABLE ET AL 2,316,566

X-RAY TUBE TIMER

Filed April 1, 1941 2 Sheets-Sheet 1

Fig. 1.

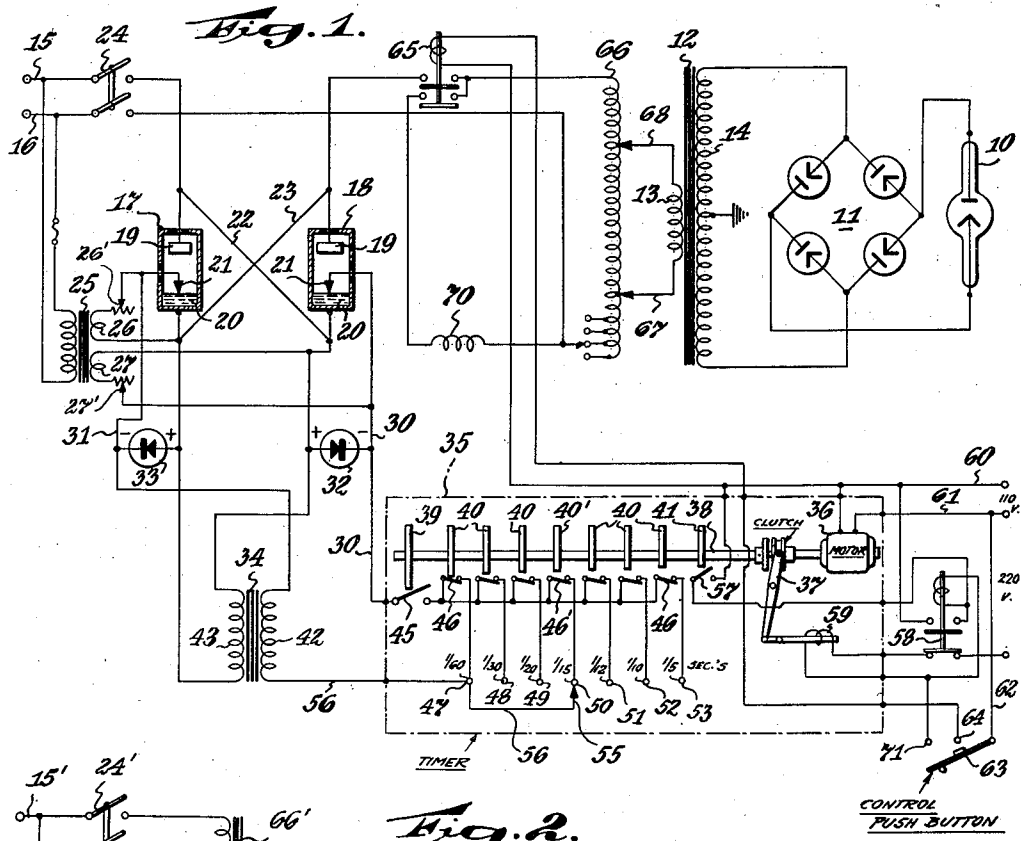
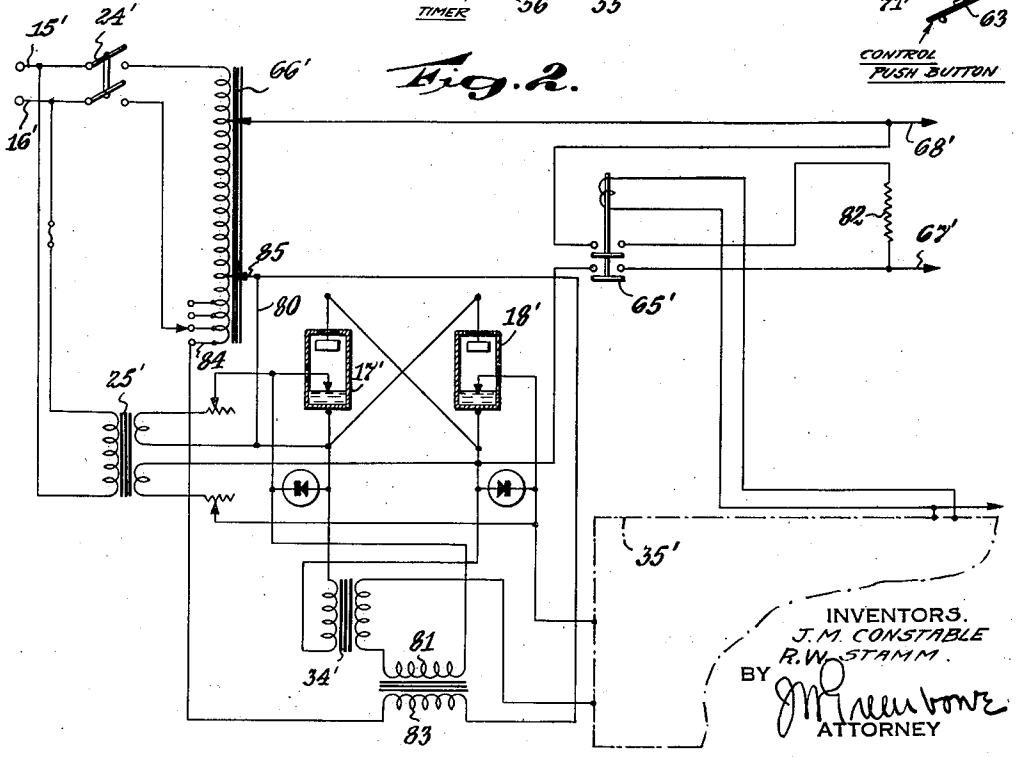


Fig. 2.



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Fig. 3.

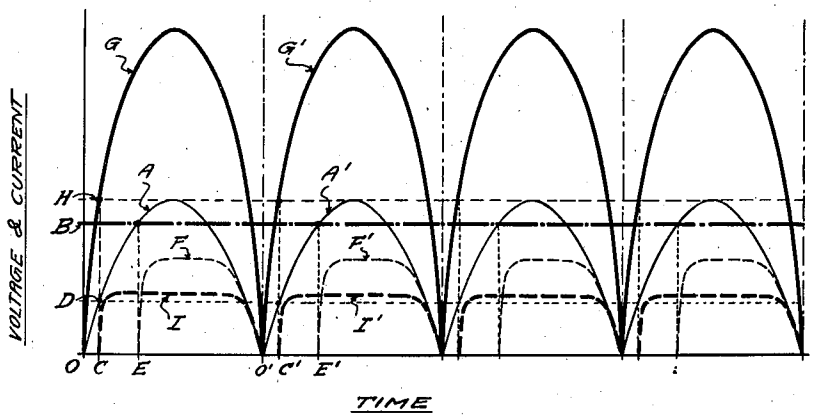


Fig. 4.

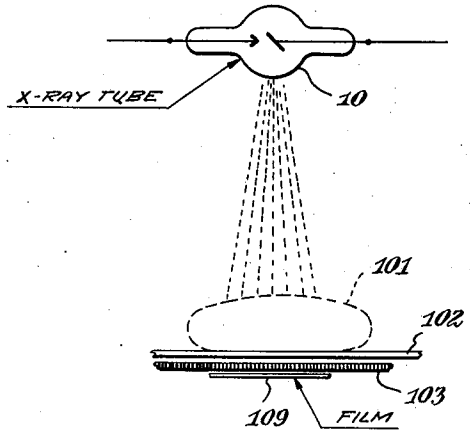
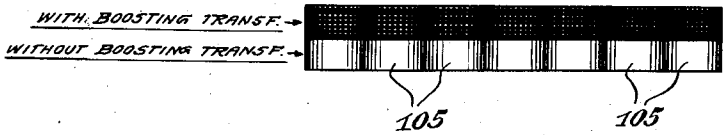


Fig. 5.



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2,316,566

X-RAY TUBE TIMER

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Application April 1, 1941, Serial No. 386,276

13 Claims. (Cl. 250—95)

Our invention relates to power circuits and especially circuits used in timing the application of power in circuits having a high power factor such as X-ray timing circuits.

An object of our invention is to utilize the ignitron or make-alive type of discharge device in a power circuit having a high power factor.

Another object of our invention is to insure the operation of an electric valve, such as an ignitron, in circuits having a high power factor without the use of complicated auxiliary apparatus.

Still another object of our invention is to avoid applying interrupted and peaked voltage waves to an X-ray tube whereby grid lines may be produced on the film from the "Bucky" grid.

Still another object of our invention is to assure the production of X-rays at the beginning of the periods when the X-ray tube is supplied from a source of periodically pulsating current.

A specific object of our invention is to provide a very accurate timing circuit for X-ray devices.

Other objects and advantages of the invention will be apparent from the following description and drawings in which:

Fig. 1 is a diagrammatic circuit arrangement embodying our invention.

Fig. 2 is a diagrammatic circuit illustrating a modification of a portion of the circuit of Fig. 1.

Fig. 3 is a graph illustrating current and voltage condition in the circuit of Fig. 1.

Fig. 4 is a diagrammatic view of of an X-ray tube, body portion, Bucky grid and film.

Fig. 5 is a radiograph illustrating the presence, in the lower portion, and the absence, in the upper portion, of Bucky grid lines.

Extensive industrial use has been made of the ignitron or make-alive type of discharge device, such as that described in the patent of Slepian and Ludwig, 2,069,283, issued February 2, 1937, in circuits having a low power factor. Such devices have generally a mercury pool cathode and a starting electrode, called an igniter or make-alive, of high resistance material, such as boron-carbide, partly immersed in the mercury.

The igniter is connected to the anode, with the result that, when a positive half cycle of alternating current is applied to the anode and igniter, a cathode spot is formed on the surface of the mercury by the igniter provided sufficient voltage is applied to the igniter. Generally, 70 to 200 volts are necessary to insure the cathode spot. The discharge transfers to the anode and the ignitron breaks down or fires.

In low power factor circuits, such as welding circuits, the voltage wave is so much displaced from the current wave that, when the beginning of the positive current half cycle is applied to the igniter, the phase of the voltage is near the peak of the voltage half cycle, thus insuring the firing of the ignitron. Otherwise complicated and costly phase shifting auxiliary devices have to be used to shift the voltage phase.

It is one of the outstanding objects of our invention to utilize ignitrons in a high power circuit and insure their firing without the utilization of complicated and costly auxiliary apparatus. In this circuit invention we preferably utilize the ignitrons as electric valves to pass the current on to the load circuit and the ignitrons are in turn preferably controlled by a timer.

Our invention has special application to an X-ray tube circuit.

One of the main problems in connection with the utilization of X-ray tubes is the accurate control of the time of exposure. This timing is made difficult by the high voltage of the tube, and this high voltage is, of course, stepped up from low voltage lines with the result that these low voltage lines must carry very high currents in order to have the voltage stepped up to that desired for the X-ray tube.

It is highly desirable that the X-ray timing circuit energize the X-ray tube near the beginning of a voltage wave, especially if a Bucky grid is used. The ordinary ignitron circuit, such as used in welding, etc., will delay firing the ignitron until the pulsating voltage reaches the minimum voltage required to create the discharge in the ignitron. This delay causes a sudden high peaked current wave the last portion of the half cycle. Dosage meters connected to the circuit generally do not give a true picture of this brief and intense X-ray production and may lead the doctor to assume the exposure has been longer than it actually was.

Where a Bucky grid is used, the sudden rush of a high peaked current through the X-ray tube is apt to produce grid lines on the film, especially if the movement of the grid is approximately in synchronism with the pulsating current as the shadows caused by the lead grid will be repeated at approximately the same portion of the film during exposure.

In order to insure that the ignitrons fire during the early part of the half cycle to provide a smooth wave form of current through the X-ray tube with a minimum of interruption, we supply means to apply additional voltage to the igniter or starting electrode. Our preferred form of this means is a boosting transformer which will be

hereinafter described in connection with the circuit illustrated on the drawings.

Our invention, while it has other uses, is especially adapted for accurately and silently applying the electric energy in a smooth wave form to the X-ray tube for the desired exposure and then interrupting it. In Fig. 1 we have diagrammatically illustrated the X-ray tube 10 supplied from the well known full wave rectifier bridge 11, which is in turn energized from the transformer 12 having a low voltage primary 13 and a very high voltage secondary 14. Supply lines 15 and 16, generally of 110 or 220 volts alternating current, supply the desired electrical energy. Intermediate the supply lines 15 and 16 and the step-up transformer 12 we utilize a special timing circuit which primarily consists of two ignitron type discharge valves or devices 17 and 18. These ignitrons are composed of an anode 19 and a mercury pool cathode 20 having partly immersed therein a make-alive 21, generally consisting of boron carbide, although other high resistance material may be used. The make-alive 21 will create a cathode spot on the mercury pool and permit the discharge through the device. The ignitrons are inversely connected to the supply line. That is, the anode circuit of the ignitron 17 is connected by 22 to the cathode connection of the ignitron 18, and the anode connection of the ignitron 18 is connected to the cathode connection of the ignitron 17 by 23. This inverse connection of the ignitrons will permit current to flow through the tube having the proper half cycle for the discharge when a cathode spot is produced on the pool by the make-alive electrode 21. Any desired type of switch 24 may be inserted between the supply lines and the ignitrons.

In order to provide uniformity between the two ignitrons, we connect a heating transformer 25 to the supply lines and provide two secondaries 26 and 27 with connections to the make-alive of each ignitron, including adjustable resistances 26' and 27'. The other end of the secondary is connected to the cathode. The heating current passes through both of the ignitors to the cathode, but this heating current is only a fraction of an ampere and not sufficient to create a cathode spot. If one of the make-alives is of a high resistance, the resistances are adjusted in the two make-alive circuits so that the starting electrodes will have the same response characteristics to additional voltage applied thereto. These heating transformers prevent differences in the firing of the ignitrons and produce similar succeeding half cycles of pulsating current waves to the X-ray tube. The heating circuits produce a substantially constant source of X-rays because the two ignitrons are made to have the same response characteristics.

A timing means 35 provides a connection common to the starting electrode circuit of each ignitron. This connection may be made and interrupted for any predetermined interval of time as hereinafter explained. We prefer to utilize the anode connection method of firing the ignitrons and have devised the circuit arrangement disclosed in Fig. 1 as a particularly advantageous method. The exterior connection 22 from the anode of the first ignitron 17 to the cathode of the second ignitron 18 is connected through a unidirectional connection 32 to a connection 30 leading to the timer 35. This unidirectional connection 32 is preferably a copper oxide rectifier, although other types of rectifiers may be used. The starting electrode 21 of the ignitron 18 is also connected through 32 to the same end of the timer connection in 35.

The starting electrode or make-alive 21 of the igniter 17 is connected by 31 through a winding 42 of a boosting transformer 34 to the other end 56 of the make and break common connection in the timer 35. The exterior connection from the anode of the second ignitron 18 to the cathode 20 of the first ignitron 17 is connected by a unidirectional device 33, similar to 32, to the connection 31 extending to the other end 56 of the timing means connection in 35. The cathode of ignitron 17 is connected through winding 43 of transformer 34 to the cathode of ignitron 18.

In operation, if a positive half cycle is applied to the anode of the ignitron 17, this current will travel through connection 22, rectifier 32, connection 30, timer 35 (if the connection is closed), through winding 42 to the make-alive 21 of the ignitron 17 and the ignitron will fire, passing the current from the anode to the cathode and then through connection 23 to the load circuit through transformers hereinafter described. .It will be noted that the polarity of rectifier 33 is such that all the current in 31 is allowed to pass through igniter 21 of ignitron 17.

During the next half cycle, the positive voltage is applied to the anode of the ignitron 18 and the current also travels through the connection 23, rectifier 33, connection 31, winding 42, timer 35 and connection 30 to the make-alive 21 of the ignitron 18 which fires, and the line current passes through the ignitron to the connection 22. The ignitrons accordingly alternate in firing every other half cycle to make connection to the load circuit.

The boosting transformer 34 insures the application of sufficient voltage to the igniters or make-alives to fire the ignitrons in spite of the high power factor of the circuit. It will be noted that winding 43 of boosting transformer 34 is connected between cathodes of 17 and 18. By virtue of the relatively low impedance of the transformer and load circuit, the voltage impressed on winding 43, prior to ignitron firing, is nearly equal to full line voltage. The winding 42 of transformer 34 connected between the igniters by 31, 35 and 30 and the polarity of its voltage is so arranged that its voltage adds to line voltage derived from cathode connections and results in an increased or boosted voltage applied to the igniters.

In Fig. 3 is illustrated diagrammatically the positive pulsating half sine wave voltage A applied to one of the ignitrons such as 17 by the source of alternating current 15, 16 and A' the succeeding positive pulsating half sine wave voltage applied to the other ignitron 18 on a time line.

B represents the voltage necesary to fire the ignitrons. Because of the high power factor X-ray circuit, the current will be applied to the igniter at point C. The voltage applied to the ignitron after passing through the zero point has just been built up to D at the point C and this value, without our boosting transformers, is not enough to fire the ignitrons. The firing is delayed until E is reached which is graphically the projection of the intersection of the line B and the voltage half cycle. In other words, E is the point where the voltage applied to the ignitrons has been built up to the minimum value necessary to start the discharge. The current flows through the ignitron in a high peaked

wave F for the remaining part of the half cycle. The effect on the X-ray tube is that first there is an interruption of the current during a large part of the cycle represented by OE and then an intense current through the tube. During the next half cycle the ignitron 18 will delay firing and the discharge current will take the form of the high peaked wave F'.

Dosage meters attached to X-ray apparatus generally indicate the product of the intensity of the X-rays and the time the tube is actuated. Such meters would not take into account the elapsed time OE and O'E' that represent an appreciable portion of the cycle and the ordinary doctor would assume the exposure to be longer than it was.

A more serious problem of interrupted high peak currents through the X-ray tube is the production of grid lines on the film. In Fig. 4 is represented the X-ray tube 10 sending its rays through a patient 101 resting on a table 102 above a film 104. Intermediate the table and the film is the well known Bucky grid, such as described in Patent 1,164,987, issued December 21, 1915. This grid is made of parallel lead plates to permit the direct rays to pass therethrough but to intercept those which are refracted and scattered in passing through the patient and would fog the film. This Bucky grid is kept in motion.

The effect of the interrupted high peaked current waves through the X-ray tube is to produce shadows of the grid on the X-ray film, especially if the movement of the grid places the lead plates at approximately the same place during the last part of the half cycle of current through the tube. These shadows 105 are illustrated in the lower half of Fig. 5 and make uncertain, if not impossible, an accurate interpretation of the X-ray picture.

Our use of a boosting transformer 34, however, produces a smooth, unpeaked current wave through the ignitron and X-ray tube and gives the even X-ray film background illustrated in the upper portion of Fig. 5. The voltage across the ignitron 17 is not that of the curve A, but that of G, and the difference between G and A is because of the boosting effect of the line voltage applied by this boosting transformer.

When current is applied at C the voltage is above the line B and H and the ignitron fires at once with a substantially smooth wave form I. This wave form continues for practically the entire half cycle to be succeeded by a similar wave form I' through the other ignitron 18. The result is that there is only a very slight interruption of the current at OC and O'C' and the dosage meter reading is a substantially correct value. Most important of all, however, is the absence of grid shadows because of the smoother current wave form. The point C has been displaced from O more than necessary for the purpose of illustration, but may more nearly coincide with O. The windings of the boosting transformer may have more boosting effect than that illustrated, if desired.

This booster arrangement has other application besides that of timing X-ray tubes. It will also be noted that this boosting transformer is simple and inexpensive in comparison with complicated phase-shift and other types of auxiliary apparatus heretofore used.

The timer 35 is preferably of the type having a motor 36 connected by a clutch 37 to a shaft 38 having a plurality of revolving cams. These cams are in three groups, namely, one cam 39, a plurality of timing cams 40, and a holding cam 41. The purpose of the first cam 39 is to close a normally opened contact 45 that makes connection with a plurality of normally closed contacts 46 in the path of the cams 40. Each of these contacts has a connection to a plurality of contacts 47, 48, 49, 50, 51, 52, and 53. The cams 40 are staggered about the shaft 38 so that each one will break the contact 46 at a certain specified interval of time from the closing of the switch 45 by the first cam 39. The speed of the motor and the positions of the cams can be so designed that after the cam 39 has closed the contact 45, the next cam 40 will open the contact to the contact point 47 1/30 of a second later. The contact to the contact point 48 will be opened in 1/30 of a second, and the remaining preferably in 1/20, 1/15, 1/12, 1/10, and 1/5 of a second after the closing of the contact 45 by the first cam 39. The action of the timer can accordingly be determined by inserting an end 55 of a connection 56 into the proper contact point for the length of the desired exposure of the X-ray tube. The other end of the connection 56 is connected to the winding 42 of the boosting transformer 34 which has previously been described. The last cam 41 on the shaft closes a normally open contact 57 that is connected through a relay 58 to release, by means of the solenoid plunger arrangement 59, the clutch 37 between the motor and the shaft 38. The motor is supplied with a commercial circuit from the supply lines 60, 61, preferably of 110 volts. From these supply lines 60 and 61 extend a connection 62 to a control push button 63.

This control push button has a first operating contact 64 extending to a relay switch 65 connected to the inversely connected ignitrons and a transformer 66, preferably of the low impedance auto-transformer type. From this auto-transformer extend connections 67, 68 to the secondary 13 of the step-up transformer 12 supplying the X-ray tube 10. The other end of the transformer 66 has an inductance 70 in parallel with the auto-transformer winding and the relay switch connections 65 to make the current wave shape more effective for firing the ignitrons 17 and 18. The closing of the first contact 64 of the control push button accordingly connects the ignitron circuit to the X-ray tube 10, but does not energize the make-alive to create the discharge through the ignitrons. The closing of the second contact 71 on the control push button energizes the solenoid 59 to engage the revolving shaft 38 to the motor 36. The cam 39 then closes the contact 45 to complete the electrical circuit to the make-alives 21 of the ignitrons 17 and 18 to create a cathode spot therein and the discharge through the proper ignitron.

The other cams 40 immediately begin breaking the contacts 46 at the various time intervals, and when the particular cam 40' opens the contact 46' to the last preset connection 55, then the ignitron circuit to the make-alives is interrupted and the discharge stops. The time is determined by the last preset connection, such as 55, as the time would be one-fifteenth of a second whether any or all of 47, 48, and 49 were connected to 56. The cam 41 at the end of the shaft will close the contact 57 and this will energize the relay 58, which de-energizes the clutch and forms a self-holding circuit for this relay 58. This relay 58 not only is utilized to open the clutch energiza-

tion circuit, but also maintains the clutch circuit interrupted as long as the operator has the control push button in closed position. If it were not for the holding of winding of the relay 58, the clutch would again be energized.

In Fig. 2 is illustrated a slight modification of the left-hand portion of Fig. 1 in that the timing circuit itself is interposed between the auto-transformer 66' and the connections 67', 68' to the high voltage transformer 12. In Fig. 2 we have not illustrated the high voltage transformer 12, full wave rectifier 11, and the X-ray tube 10, since they are identical with Fig. 1. We have likewise merely illustrated diagrammatically the motor and cam arrangement 35' in Fig. 2.

The auto-transformer is connected to the supply lines 15' and 16' through the switch 24'. The ignitrons 17' and 18' are inserted in a connection 80 to the auto-transformer. The heating transformer 25' for the make-alive electrodes of the ignitrons is similar to that of Fig. 1. In addition, however, in Fig. 2 an additional boosting transformer 81 is provided having its secondary winding in series with the winding of the boosting transformer 34'. The primary of boosting transformer 81 is connected permanently between a tap 84 and a tap 85 on the auto-transformer 66'. As the voltage to be controlled by the ignitrons 17' and 18' is lowered by means of the variable tap 85, the voltage to the primary 83 of transformer 81 is automatically increased. A resistance 82 is also connected in parallel with the primary winding of the high voltage transformer upon the closure of the relay 65'. Otherwise, the circuit is similar in respect to that of Fig. 1.

It is apparent that we have described a very accurate and reliable timing mechanism for X-ray tubes and one which can be operated merely by a control push button. It is apparent, however, that many modifications may be made in the preferred embodiments illustrated, and accordingly we desire only such limitations to be imposed upon our invention as are necessitated by the spirit and scope of the following claims.

We claim:

1. An electric power system comprising in combination, a load circuit and circuit means connecting said load circuit to a source of alternating current comprising a pair of reversely connected arc discharge devices having an anode and a cathode, a starting electrode in the first discharge device, an exterior connection between said starting electrode and the anode of the same first discharge device, a starting electrode in the second discharge device, a second exterior connection between said last-mentioned starting electrode and the anode of the second discharge device, and means for applying the voltage difference between said arc discharge devices to increase the voltage applied to said starting electrodes, each of said arc discharge devices comprising a mercury pool cathode cooperating with said anode, said starting electrodes comprising high resistance material partially immersed in said mercury pool, and means applying a heating current between the starting electrode and mercury pool not sufficient to ignite the discharge.

2. An electric power system comprising in combination, a load circuit and circuit means connecting said load circuit to a source of alternating current comprising a pair of reversely connected arc discharge devices having an anode and a cathode, a starting electrode in the first discharge device, an exterior connection between said starting electrode and the anode of the same first discharge device, a starting electrode in the second discharge device, a second exterior connection between said last-mentioned starting electrode and the anode of the second discharge device, and means for applying the voltage difference between said arc discharge devices to increase the voltage applied to said starting electrodes, said first and second exterior connections having a common portion and said common portion having a booster transformer primary in series therewith, and a secondary for said booster transformer in series with the cathodes of both said arc discharge devices for adding to the line voltage of each.

3. An electric power system comprising in combination, a load circuit and circuit means connecting said load circuit to a source of alternating current comprising a pair of reversely connected arc discharge devices having an anode and a cathode, a starting electrode in the first discharge device, an exterior connection between said starting electrode and the anode of the same first discharge device, a starting electrode in the second discharge device, a second exterior connection between said last-mentioned starting electrode and the anode of the second discharge device, and means for applying the voltage difference between said arc discharge devices to increase the voltage applied to said starting electrodes, said first and second exterior connections having a common portion and said common portion having a booster transformer primary in series therewith, and a secondary for said booster transformer in series with the cathodes of both said arc discharge devices for adding to the line voltage of each, timing means in series with said primary of the booster transformer, said timing means comprising a plurality of contacts and means to predetermine the interval of time that the arc discharge devices are fired by the making and breaking of said contacts.

4. An electric power system comprising in combination, a load circuit and circuit means connecting said load circuit to a source of alternating current comprising a pair of arc discharge devices each having an anode, cathode, and starting electrode, an exterior connection from the anode of each discharge device to the cathode of the other discharge device, a timing mechanism, a circuit supplying unidirectional line current to each said starting electrode, said circuit including the primary of a booster transformer, and a secondary for said transformer connected in series with each starting electrode for adding to the line voltage to the starting electrode for insuring firing of the arc discharge device.

5. An electric power system comprising in combination, a load circuit and circuit means connecting said load circuit to a source of alternating current comprising a pair of arc discharge devices having an anode, cathode, and starting electrode, an exterior connection from the anode of each discharge device to the cathode of the other discharge device, timing means comprising a connection adapted to be interrupted at a preselected interval of time, the starting electrode of the first discharge device being connected to one end of said timing means connection, a unidirectional connection from the interconnection of the anode of the second discharge device and the cathode of the first discharge device to the first-mentioned end of said timing means connection, a connection from the starting electrode of said second discharge device to the other end

of said timing means connection, and a unidirectional connection from the interconnection of the anode of the first discharge device and the cathode of the second discharge device to the other end of said timing means connection.

6. An electric power system comprising in combination, a load circuit and circuit means connecting said load circuit to a source of alternating current comprising a pair of arc discharge devices having an anode, cathode, and starting electrode, an exterior connection from the anode of each discharge device to the cathode of the other discharge device, timing means comprising a connection adapted to be interrupted at a preselected interval of time, the starting electrode of the first discharge device being connected to one end of said timing means connection, a unidirectional connection from the interconnection of the anode of the second discharge device and the cathode of the first discharge device to the first-mentioned end of said timing means connection, a connection from the starting electrode of said second discharge device to the other end of said timing means connection, and a unidirectional connection from the interconnection of the anode of the first discharge device and the cathode of the second discharge device to the other end of said timing means connection, two inductively coupled windings, one of said windings connected across the two discharge devices and the other winding being in the connection between one end of the timing means connection and a starting electrode whereby the voltage difference between the two discharge devices increases the voltage applied to said starting electrodes.

7. An electric power system comprising in combination, a load circuit and circuit means connecting said load circuit to a source of alternating current comprising a pair of arc discharge devices having an anode, cathode, and starting electrode, an exterior connection from the anode of each discharge device to the cathode of the other discharge device, timing means comprising a connection adapted to be interrupted at a preselected interval of time, the starting electrode of the first discharge device being connected to one end of said timing means connection, a unidirectional connection from the interconnection of the anode of the second discharge device and the cathode of the first discharge device to the first-mentioned end of said timing means connection, a connection from the starting electrode of said second discharge device to the other end of said timing means connection, and a unidirectional connection from the interconnection of the anode of the first discharge device and the cathode of the second discharge device to the other end of said timing means connection, the cathode and starting electrode of each of said discharge devices being respectively a mercury pool and a high resistance material partially immersed therein.

8. An electric power system comprising in combination, a load circuit and circuit means connecting said load circuit to a source of alternating current comprising a pair of arc discharge devices having an anode, cathode, and starting electrode, an exterior connection from the anode of each discharge device to the cathode of the other discharge device, timing means comprising a connection adapted to be interrupted at a preselected interval of time, the starting electrode of the first discharge device being connected to one end of said timing means connection, a unidirectional connection from the interconnection of the anode of the second discharge device and the cathode of the first discharge device to the first-mentioned end of said timing means connection, a connection from the starting electrode of said second discharge device to the other end of said timing means connection, and a unidirectional connection from the interconnection of the anode of the first discharge device and the cathode of the second discharge device to the other end of said timing means connection, the cathode and starting electrode of each of said discharge devices being respectively a mercury pool and a high resistance material partially immersed therein, and means applying a heating current to said high resistance material.

9. In combination an X-ray device and a power circuit therefor, said circuit comprising connections to low voltage lines, electric valve means in one of said lines, a transformer having primary connections to said low voltage lines and having a high voltage secondary connected to said X-ray device, said electric valve comprising a pair of arc discharge devices having an anode, cathode, and starting electrode, an exterior connection from the anode of each discharge device to the cathode of the other discharge device, timing means comprising a connection adapted to be interrupted at a preselected interval of time, the starting electrode of the first discharge device being connected to one end of said timing means connection, a unidirectional connection from the interconnection of the anode of the second discharge device and the cathode of the first discharge device to the first mentioned end of said timing means connection, a connection from the starting electrode of said second discharge device to the other end of said timing means connection, and a unidirectional connection from the interconnection of the anode of the first discharge device and the cathode of the second discharge device to the other end of said timing means connection.

10. A system applying a source of alternating current to a load, comprising in combination, conductors to be connected to the terminals of a source of alternating current between which a difference of potential exists, a first arc discharge device providing a cathode having an igniter in contact therewith connected to one of said conductors, a second arc discharge device providing a cathode having an igniter in contact therewith connected to another of said conductors, said arc discharge devices each having anodes, circuits from the anodes and cathodes to the load applying full wave rectified potential thereto, control means interconnecting said igniters, means for impressing a first potential insufficient to produce a cathode spot between said cathode of the first arc discharge device and the igniter in contact therewith, means for impressing a second potential insufficient to produce a cathode spot between said cathode of the second arc discharge device and the igniter in contact therewith, means for adjusting said potentials so as to compensate for differences in the resistance of said igniters, and means for applying a controlled potential to said ignitors sufficient to form a cathode spot.

11. A system for use in energizing an X-ray device from a source of periodically pulsating current to produce X-ray photographs, the combination comprising electric discharge valve means having starting electrode means inter-

posed between said source and said device, means for impressing impulses on said starting electrode means to render said valve means conductive during a predetermined number of periods of said source, and supplementary means adding to the said impressed impulses for assuring that said valve means is rendered conductive substantially at the beginning of each of said number of periods, said last-mentioned means including inductively arranged windings the secondary of which is connected to the starting electrode and adapted to increase the voltage applied to said starting electrode.

12. A system for use in energizing an X-ray device from a source of periodically pulsating current to produce X-ray photographs, the combination comprising two connected electric discharge valves having each an anode and a cathode and having each a starting electrode means interposed between said source and said device, means for impressing impulses on said starting electrode means to render said valves alternately conductive during a predetermined number of periods of said source, circuits from the anodes and cathodes of said valves to said device applying full wave rectified potential to said device, and supplementary means adding to the said impressed impulses for assuring that said valves are rendered alternately conductive at the beginning of each of said number of periods.

13. A system for use in energizing an X-ray device from a source of periodically pulsating current to produce X-ray photographs, the combination comprising two connected electric discharge valves having each an anode and a cathode and having each a starting electrode means interposed between said source and said device, means for impressing impulses on said starting electrode means to render said valves alternately conductive during a predetermined number of periods of said source, circuits from the anodes and cathodes of said valves to said device applying full wave rectified potential to said device, and supplementary means adding to the said impressed impulses for assuring that said valves are rendered alternately conductive at the beginning of each of said number of periods, said last-mentioned means including inductively arranged windings adapted to increase the voltage applied to said starting electrodes.

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