Dec. 19, 1950 E. W. TITTERTON 2,534,758

X-RAY SYSTEM

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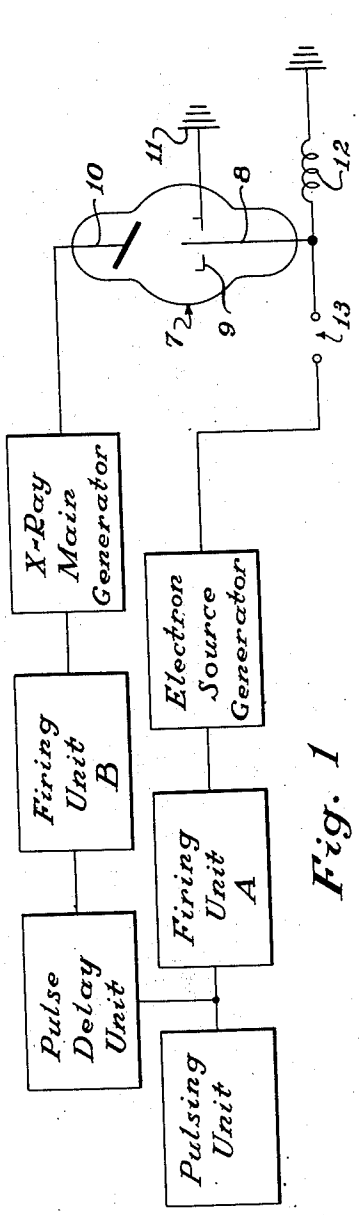


Fig. 1

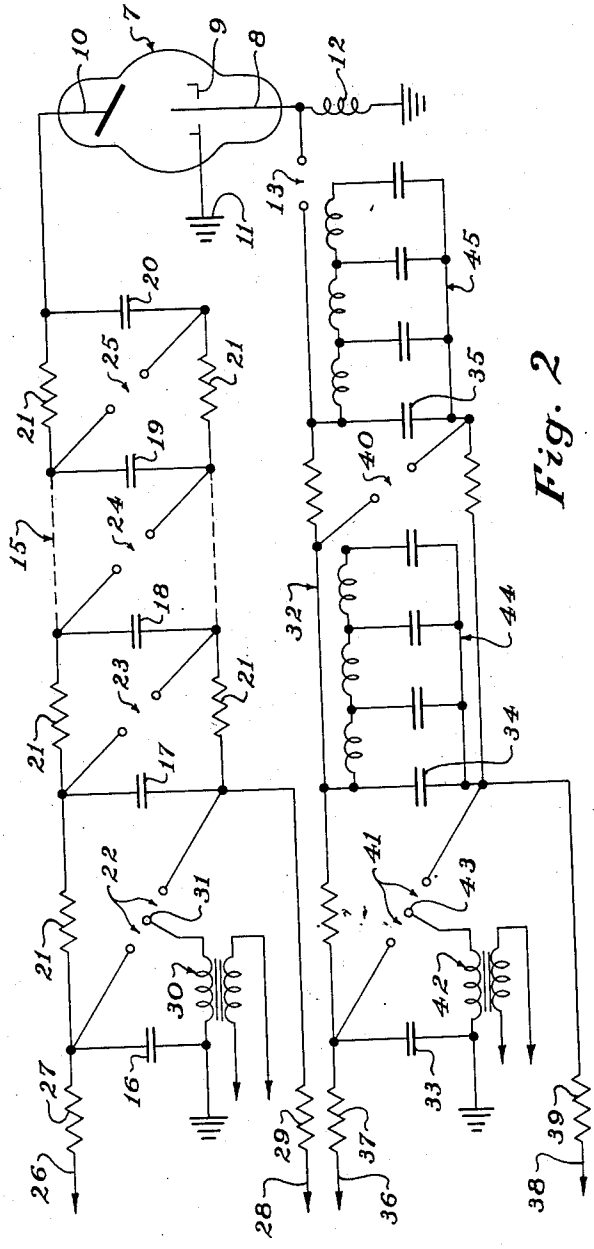


Fig. 2

WITNESSES

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## X-RAY SYSTEM

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3 Claims. (Cl. 250—98)

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This invention relates to X-ray systems and particularly to controlling means for activating an X-ray tube at predetermined times with an accuracy of the order of a tenth of a microsecond.

In the investigation of many rapidly occurring events or the examination of bodies undergoing rapid change, X-ray techniques have received widespread acceptance. The usual arrangement in conducting such observations generally includes an X-ray tube of desired characteristics and an X-ray sensitive film suitably cased disposed at opposite sides of the object or path of the event being studied. A source of potential is provided for the activation of the X-ray tube and means are provided for timing the production of X-rays to the occurrence of the event or change. Such last mentioned means have generally consisted of various types of switching circuits, photoelectrically or otherwise activated, which at best operated with considerable fluctuation in time. Furthermore, activation of the X-ray tube itself was generally brought about by the employment of a surge generator capable of producing an instantaneous high potential difference between cathode and anode of the tube.

One such type of surge generator is known as the Marx generator and comprises a plurality of capacitors interconnected so as to be charged in parallel from a source of moderate voltages and discharged in series to produce an additive surge of potential. Such generators were heretofore generally employed in a double ended manner so that the capacitors formed upon discharge a series circuit with the X-ray tube. The discharge of the tube under such circumstances took place rather haphazardly in time and accuracies in timing of fractions of a microsecond were unobtainable.

While attempts to effect greater accuracy in the time of discharge of an X-ray tube were made by improved construction of X-ray tubes and the addition of auxiliary electrodes, many shortcomings remained. The systems associated with the tubes were characterized by an inflexibility which prevented changes to accommodate for changes in tube characteristics or operating conditions and thus the operation of these improved tubes left much to be desired.

In copending U. S. patent application S. N. 776,237, filed September 26, 1947, now U. S. Patent No. 2,524,240, granted to Titterton and Voorhies October 3, 1950, there is described an improved X-ray system and surge generator for producing X-ray bursts with a high degree of

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timing accuracy. The invention there described also presents other advantages in the construction and operation of such a system.

It is an object of the present invention to provide an X-ray system for the observation of rapidly occurring phenomena.

It is a further object of the present invention to provide an X-ray system in which the time of production of X-rays is governed to fractions of a microsecond.

It is a further object of the present invention to provide a flexible X-ray producing system which is readily adapted to changes in conditions of operation or changes in the X-ray tube characteristics.

Other objects and advantages of the present invention will be apparent from the following description of a presently preferred embodiment in conjunction with the drawings made part of this specification in which:

Figure 1 is a schematic diagram indicating the mode of operation of the system of the present invention.

Figure 2 is a circuit diagram of the main elements of the system.

It is immediately apparent from an examination of the drawings that the instant system employs as the X-ray emitting element a conventional X-ray tube having a cathode, a directly grounded electrode and a target electrode. With such a tube, initial energization of the cathode is accomplished by establishing a low power discharge to the grounded electrode. In a sense, this initial cathodic energization prepares the cathode for substantial electron emission when the full or main voltage surge is placed across the cathode and target electrode. This initial energization was recognized as useful at an early date with respect to hot cathode X-ray tubes and systems employing the same have been described as for example in U. S. Patent No. 1,250,731, granted to Waite December 18, 1917, and U. S. Patent No. 1,983,643, granted to Simon et al. December 11, 1934.

In combination with such a tube the present invention provides a main generator circuit associated with the target electrode, an electron source generator circuit associated with the cathode, each of said generator circuits being controlled by a separate triggering circuit, said triggering circuits in turn being associated in time delay relationship with a source of initiating pulses.

Referring to the drawings and more specifically Figure 1 thereof, the cooperating elements of the

system are indicated largely by box diagram in order to point out clearly the benefits of the combination. An X-ray tube generally referred to by numeral 7 is seen to comprise an outer envelope which serves to support in fixed relationship cathode 8, grounded electrode 9 and target electrode 10. Electrode 9 is connected directly to the ground point of the system as indicated at 11. Cathode 8 is normally maintained at ground potential through the inductance 12 and is associated through spark gap 13 with a source of moderate voltage labeled electron source generator. This source generator, as will be explained below, is operative at a predetermined time to supply a voltage pulse to cathode 8 to establish a momentary electron discharge between said cathode and electrode 9, inductance 12 being chosen of a value to block the passage of said pulse to ground. The source generator is in turn activated by a so-called firing unit A, e. g. a pulse transformer which supplies a fast rising triggering pulse originating at the single pulsing unit to said generator.

Target electrode 10 is directly associated with a surge or main generator capable of supplying a substantial positive voltage surge and instantaneously establishing a high potential difference across electrode 10 and cathode 8, thus initiating electron discharge therebetween with consequent X-ray emission at the said target. The main generator is activated by firing unit B, also a pulse transformer circuit as firing unit A, which receives the pulse from the single pulser unit through a pulse delay unit. The delay unit is preferably variable in the length of delay provided in order to provide flexibility required by variations in operating conditions. The delay required is usually in the range from zero to two microseconds and it is desirable to provide a delay circuit which is variable in small steps in this range.

It is thus seen that to produce an X-ray burst or flash the pulsing unit is suitably activated and produces a pulse which is fed directly to the delay unit and to firing unit A. Firing unit A passes the pulse to the source generator causing surge discharge thereof and impressing between cathode 8 and anode 9 an instantaneous potential, e. g. about one hundred and fifty kilovolts, causing electron emission at cathode 8 to take place. The pulse passed to the delay unit is suitably delayed, for a microsecond for example, and is then fed to firing unit B, thus initiating surge discharge of the main generator and consequent establishment of a high potential difference between target electrode 10 and cathode 8 subsequent to the initiation of electron emission.

Under such operation it has been determined that the time of X-ray emission can be accurately controlled to within a fraction of a microsecond and in fact to within 0.1 microsecond. As a result the accurate determination of the conditions existing at a particular predetermined time in a body undergoing rapid change can be attained.

Turning now to Figure 2, further advantages of the present system will be apparent. By maintaining cathode 8 at ground potential single and surge generators can be employed, and triggering thereof accomplished by single trigger gaps in place of the two gaps as shown in the copending application of Titterton and Voorhies cited above. Thus, for example the main generator, generically designated by reference numeral 15, is seen to comprise a plurality of capacitors 16 through 20 (the broken lines indicating that any predetermined number may be used) interconnected in parallel by resistors 21 to permit charging to predetermined potentials and interconnected in series by gaps 22 through 25 so that the discharge of said capacitors is additive. Capacitor 16 is charged positively with respect to ground from a positive potential supply indicated by conductor 26 and limiting resistor 27. Capacitors 17 through 20 on the other hand float with respect to ground, being charged equally positive and negative from the positive potential supply indicated by conductor 26 and the negative potential supply indicated by conductor 28 and limiting resistor 29. Between capacitors 16 and 17 gap 22 is provided to interconnect said capacitors in series for discharge. Said gap 22 is of well-known construction and comprises a pair of spaced apart electrodes between which is interposed a trigger electrode 31 adapted to be pulsed through auxiliary pulse transformer 30, the primary 31 of which is directly connected to firing unit B (Figure 1). In such a gap the potential difference between the main electrodes existing by reason of the charge on capacitors 16 and 17, is insufficient to break down in an arc discharge; whereas upon imposition of a sharp pulse on trigger electrode 31, the gap does break down.



With such breakdown, the positive voltage stored in capacitor 16 passes to capacitor 17 and thus overloads gap 23 which in turn breaks down; this stepwise breakdown through the generator ultimately resulting in the application of a positive high potential surge between target 10 and cathode 8 giving rise to X-ray emission.

Source generator 32, which in the normal operation of the system, is activated before main generator 15 as noted above, also comprises a plurality of capacitors, one of which, capacitor 33, is charged positively with respect to ground and the others, for example capacitors 34 and 35 float, i. e. are charged both positively and negatively from the positive supply indicated by conductor 36 and limiting resistor 37 and the negative supply indicated by conductor 38 and limiting resistor 39.

The gap 40 between floating capacitors 34 and 35 is the normal two electrode type, while the trigger gap 41 between grounded capacitor 33 and capacitor 34 is of the three electrode type described above; pulse transformer 42 being employed to associate trigger electrode 43 with firing unit A (see Figure 1). Capacity terminated delay lines 44 and 45 are associated with capacitors 34 and 35 respectively, to provide continuity for a predetermined time for the arc discharge initiating output of generator 32.

In operation the application of a triggering pulse of electrode 43, breaks down gap 41 permitting addition of the charges on capacitors 33 and 34. In turn, as a result of being thus overloaded gap 40 breaks down and the charge on capacitor 35 is added to the output. This output is supplied across gap 13 to cathode 8 and is sufficient to initiate discharge between cathode 8 and grounded electrode 9 in anticipation of the application to tube 7 of the main voltage surge from generator 15.

Circuitwise, the other elements of the system can be of any desired construction. As the parameters thereof do not change the principles of operation here described, no detailed discussion of such elements is believed necessary. The pulser unit may be of the type to supply a single output pulse of predetermined characteristics or a plurality of them, spaced in time to permit in-

termittent X-ray flashes to be obtained from the system. The delay unit employed in association with main generator 15, likewise may be of any desired type, the significant features being the delay and pulse shape obtainable at the output thereof.

It is thus apparent that many widely different variations in the form and operation of the system of the present invention will now present themselves to one skilled in the art. As a consequence, the limitations which may appear from the description of the specific embodiment given above should only be deemed to be limiting on the scope of the invention only to the extent that they are defined in the appended claims.

What is claimed is:

1. An X-ray system comprising an X-ray tube having a cathode grounded through an inductance, a directly grounded electrode and a target electrode, first surge generator means in series between said target electrode and ground for effecting arc discharge between said target electrode and said cathode, second surge generator means in series between said cathode and ground and in parallel with said inductance for effecting arc discharge between said cathode and said grounded electrode, separate triggering means associated with each of said generator means and with each other in predetermined time delay relationship whereby said second generator means is activated to discharge in advance of



said first generator means, and a common means for activating said triggering means.

2. A system as in claim 1 in which the second surge generator means includes discharge prolongation means for effecting over a predetermined time the discharge between said cathode and said grounded electrode.

3. An X-ray system comprising an X-ray tube having a cathode grounded through an inductance, a grounded electrode, and a target electrode, first surge generator means in series between said target electrode and ground for effecting arc discharge between said target electrode and said cathode, second surge generator means in series between said cathode and ground and in parallel with said inductance for effecting arc discharge between said cathode and said grounded electrode, separate triggering means including pulse transformers associated with each of said generator means and responsive to an input pulse to activate said generator means to effect the respective tube discharges, pulse delay means associated with the triggering means for said first generator means, and pulsing means for providing activating pulses at a predetermined time to said delay means and to the triggering means associated with said second generator means.

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No references cited.