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METHOD AND SYSTEM FOR OPERATING X-RAY TUBES

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FIG 1

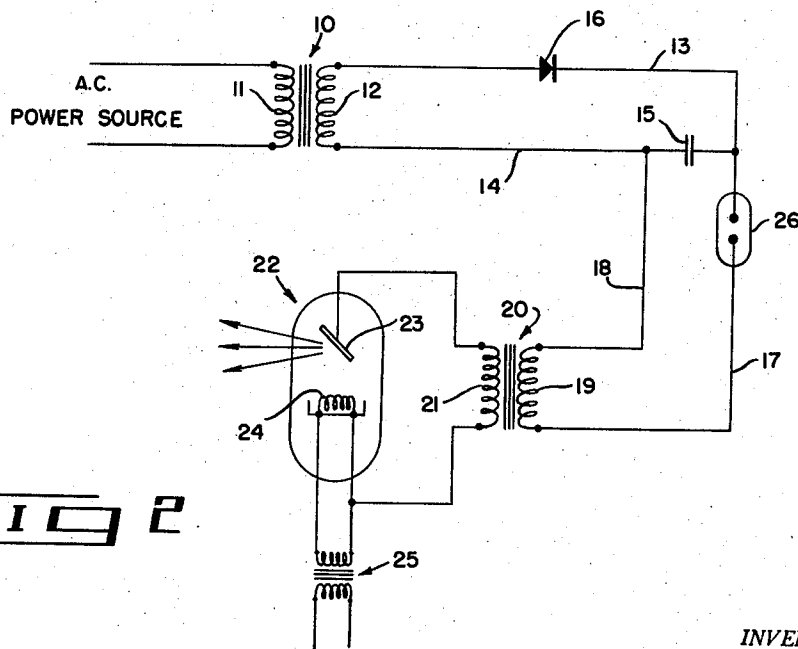
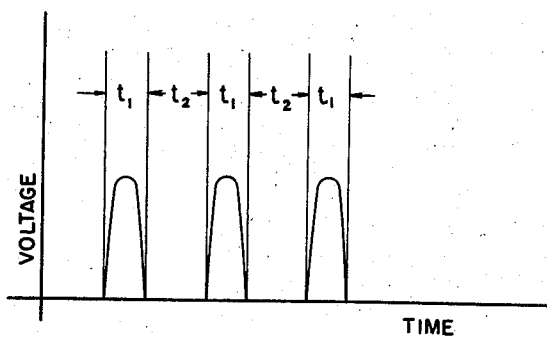


FIG 2

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METHOD AND SYSTEM FOR OPERATING X-RAY TUBES

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3 Claims. (Cl. 250—98)

The present invention relates to a new method and system for operating X-ray apparatus, and its primary object is to provide energy for X-ray tubes in the form of electric impulses with the result of higher efficiency in the tube and higher yield in X-radiation.

Generally, X-ray tubes are operated either by pulsating or by continuous high voltage direct current. The maximum safe working voltage of tubes for such operation depends on their design and is limited by their rating and safe temperature rise. Surpassing the rated voltage results in gaseous discharges mostly accompanied by arc-like discharges and finally leads to a destruction of the tube.

It is an object of the present invention to provide a method of operation for X-ray tubes whereby the peak voltage applied to a given tube can be multiplied without shortening the life of the tube.

To achieve the purpose of this invention, a given X-ray tube is fed by a train of electric impulses of short duration instead of a continuous current supply. The duration of the impulses is thereby so short that they cannot create a detrimental current avalanche within the tube. Thus it is possible to considerably increase the safe operating voltage of a particular X-ray tube without adverse effects. However, to obtain with impulses of such very short duration X-radiation of the same average magnitude as with continuous current supply, it is necessary to adjust the current of each impulse to a correspondingly higher value. Assuming for illustration an impulse duration of 10^{-6} second and feeding the tube with 10^3 such impulses per second, it becomes necessary for a similar loading of the tube that the current of each impulse carries a current 10^3 times greater than in continuous current operation. Thus, in accordance with this invention, it is advisable to reduce the duration of the voltage impulses so much that they cannot cause gaseous discharges within or around the tube but to increase the current that the root-mean-square value of a train of impulses is in order equivalent to the maximum continuous current rating of the tube.

An advantage of the impulse operation of X-ray tubes according to this invention is the fact that in case the voltage amplitude of the impulses is not greater than the voltage rating for continuous-current operation of a tube, the safety of operation is materially increased owing to reduced danger of breakdown.

Another advantage is gained by the fact that without creating dangerous operating conditions, it is possible to operate with peak voltages of the impulses which are several times higher than the permissible rated voltage of the tube. Since the efficiency of X-ray production increases approximately proportional with the square of the operating voltage, it is thus possible to achieve, for instance, with an impulse voltage of twice the rated operating voltage, four times the yield in X-radiation. In cases where increase in radiation is not necessary nor desirable, the use of smaller and lower priced tubes can be considered when employing the present impulse method.

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Still another advantage is the fact that for very intensive X-radiation, requiring, for instance, normally a peak voltage of 500 kilovolts, it is possible to employ commercial tubes, for instance such rated at 200 kilovolts, with satisfactory results when operating according to the method of this invention.

Further advantages and novel features will now be explained hereinafter in connection with the accompanying drawing in which

Fig. 1 is a graphic representation of voltage-time relationship of the impulses for operating an X-ray tube in accordance with this invention; and

Fig. 2 shows diagrammatically an arrangement of an impulse voltage source connected to an X-ray tube.

The graphic representation of Fig. 1 will help to visualize the time relation between impulse durations and intervals. The duration of the impulses t_1 is very short, of the order of one microsecond, and the intervals t_2 between successive impulses are relatively long, as a rule more than 1000 times the duration of t_1 . The Fig. 1 serves for illustration only and the relation t_1 to t_2 is not drawn to scale. It must be understood that t_1 must be very short, in fact so short that during such instant no harmful breakdown within the tube can be caused by the high potential of the impulse, which, as aforementioned, is much higher than the kilovolt rating of a particular tube.

In order to take full advantage of the energy delivered to the X-ray tube by the short but strong impulses it is necessary that for such operation the hot-filament cathode of the tube is designed for higher electron emission than for conventional operation. Considering a time relationship between t_1 and t_2 equaling 1 to 1000, the emission must be 1000-fold in order to get the whole benefit of impulse operation and not exceeding the safe temperature rise of the tube as given for continuous operation.

Such high emission as mentioned above could not be achieved in previous X-ray tube designs because it was impossible to employ cathode material of high emissivity, such as thoriated tungsten or pill material, on account of the fact that such material does not endure the continuous ion bombardment due to traces of gas in the tube. However, in operation by the impulse method the instant during which the impulse voltage is effective is too short for developing a detrimental ion avalanche and the time intervals between impulses are long enough for de-ionizing the traces of gas in the tube before a subsequent impulse occurs. Therefore, highly emissive cathode materials can be incorporated in tubes designed particularly for this purpose.

If low cost of the tubes is a primary factor, good results in the production of X-radiation by the present impulse method can be obtained with tubes of the getter type whereby the getter pill can be attached in a protected spot within the tube. Other relatively inexpensive tubes applicable in the new method provided by this invention are metal tubes somewhat similar to metal radio tubes, wherein the metal envelope is designed in accordance with electron optics to concentrate the electron stream in a focal spot for X-radiation at its inside, wherein the lead-ins to a hot-filament cathode of high emissivity project through an insulator secured in the metal wall, the vacuum within the tube is maintained by getter means attached to the inside of the envelope, and the metal envelope, serving simultaneously as anode or target, can be cooled from the outside.

Such special X-ray tubes as above described, or tubes of conventional construction when operated by the impulse method, are used in conjunction with a circuit as diagrammatically shown in Fig. 2. The primary winding 11 of the high-tension transformer 10 is connected to an alternating power source not shown. The high ten-

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sion secondary 12 of this transformer is connected by means of conductors 13 and 14 to a storage condenser 15. Since condenser 15 is to be charged by high-potential direct current, a rectifier 16 is shown inserted in conductor 13. In this connection the condenser is continually charged as long as the primary of transformer 10 is in circuit with the power source. Condenser 15 is designed for impulse discharges, i.e., it has extremely low inductance and low losses. In parallel connection with condenser 15 is shown a discharge circuit consisting of conductors 17 and 18 and the primary winding 19 of impulse transformer 20. Shown inserted in line 17 is a periodically operating switching means, here indicated in the form of a spark gap 26 which successively breaks down whenever the condenser potential surpasses the breakdown voltage of the gap. It will of course be understood that other periodic switching means can be employed and that they may be inserted anywhere in the discharge circuit. The secondary winding 21 of impulse transformer 20 is connected directly to the X-ray tube 22 which is shown diagrammatically as having an anode or target 23, and a hot-filament cathode 24 being heated by electric energy derived from a power source (not shown) through transformer 25. The X-ray beam emanating from the tube is indicated by arrows.

In operation, assuming the secondary winding of transformer 10 to be designed for charging the storage condenser 15 with 10 kilovolts, and assuming the primary winding 19 of impulse transformer 20 as having 10 turns and the secondary winding 200 turns, the anode 23 of the X-ray tube will receive impulses at a peak voltage of 200 kilovolts. These impulses carry relatively large currents, for instance, in the order of 5 amperes, and the hot filament cathode 24 must therefore be capable of emitting current of that order which is considerably higher than the average in conventional X-ray tubes. Thus, in order to take full advantage of the benefits rendered possible by the present impulse method, it is advisable to use thoriated tungsten as construction material for the hot-filament cathode of the X-ray tube employed; and design such cathode to have an emissivity of more than one ampere. The connections with respect to rectifier 16 must of course be made so that the secondary impulse wave of impulse transformer 20 is positive at the anode of the X-ray tube.

It is to be understood that the operation of an X-ray tube in a manner described herein is not intended for producing X-ray flashes whereby each electric impulse must furnish sufficient X-radiation for a particular exposure, but is provided for general X-ray practice whereby the period for passing the train of impulses is essentially of the same duration as the length of time usual in continuous current operation.

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The circuit system as shown and described is a preferred example only, and modifications are possible which are considered to fall within the scope and spirit of the invention as defined in the claims.

What is claimed is:

1. The method of operating an X-ray tube having an anode and a cathode which comprises supplying continuously electric energy to said cathode for heating the same and render it emissive for electrons; passing a train of electric energy impulses of selected peak voltage value and time spacing across anode and cathode of the tube to obtain X-ray radiation; and extending the duration of said train of impulses to last throughout the entire operating period of said tube, said time spacing between subsequent impulses of the train being selected in dependence of the energy content of each impulse such that the temperature rise of the tube in impulse operation is substantially not higher than the temperature rise allowable for continuous current operation of the tube.

2. The method of operating an X-ray tube having an anode and a cathode which comprises supplying continuously electric energy to said cathode for heating the same and render it electron emissive; passing a train of electric energy impulses of selected peak voltage value and time spacing across anode and cathode of the tube to obtain X-ray radiation therefrom; and extending the duration of said train of impulses to last throughout the entire operating period of said tube, said time spacing between subsequent impulses of the train being selected in dependence of the energy content of each impulse such that the energy content of said train of impulses as root-mean-square value is substantially equal to the continuous energy rating of the tube.

3. The method of operating an X-ray tube having an anode and a cathode which comprises supplying continuously electric energy to said cathode for heating the same and render it electron emissive; passing a train of electric energy impulses of selected peak voltage value across anode and cathode of the tube to obtain X-ray radiation therefrom; extending the duration of said train of impulses to last throughout the entire operating period of said tube; and selecting the time spacing between subsequent impulses to be more than 1000 times longer than the duration of the impulses.

References Cited in the file of this patent

UNITED STATES PATENTS

1,251,377	Hull	Dec. 25, 1917
2,032,894	Simon	Mar. 3, 1936
2,240,037	Eaton	Apr. 29, 1941
2,663,757	Lubcke	Dec. 22, 1953