July 2, 1940.

L. TONKS

2,206,710

POOL-TYPE X-RAY TUBE

Filed Sept. 1, 1938

2 Sheets-Sheet 1

Fig. 1

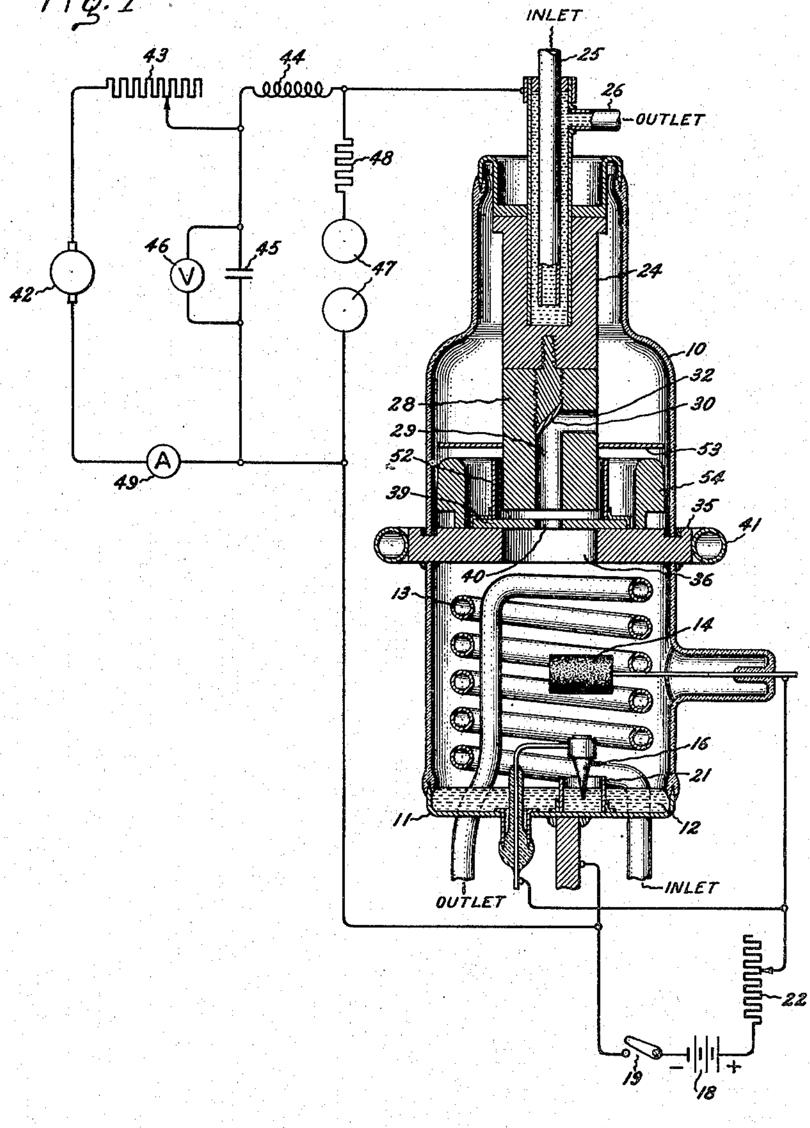

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Fig. 4.

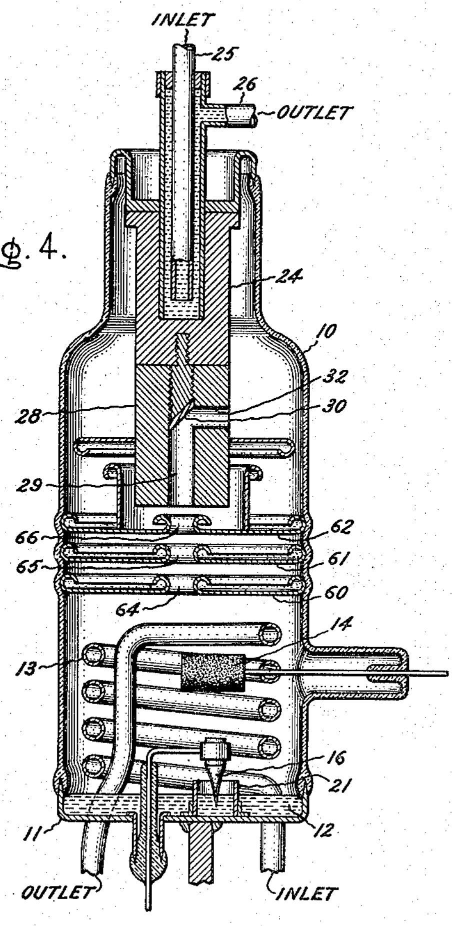


Fig. 2.

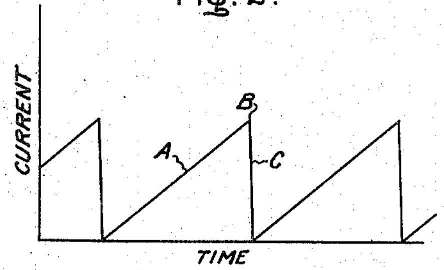
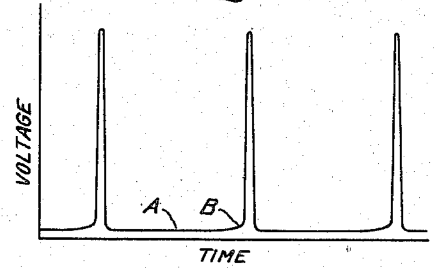


Fig. 3.



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UNITED STATES PATENT OFFICE

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POOL-TYPE X-RAY TUBE

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Application September 1, 1938, Serial No. 227,927

4 Claims. (Cl. 250—98)

The present invention relates to improvements in X-ray devices.

While it is known to produce X-rays in a device containing a minute amount of an ionizable medium (a gas or vapor), it has generally been deemed impossible to obtain such rays in a discharge space where a relatively plentiful supply of such medium is present, as is the case, for example, in a mercury pool tube operating at room temperature. This is due to the fact that the presence of a substantial quantity of ionizable medium inherently prevents the existence in the discharge space of a potential difference appreciably above the characteristic arc drop of the medium.

It is an object of my present invention to provide means whereby X-rays may be produced in a discharge device which contains a gas or vapor at a pressure materially above the pressures previously considered feasible for such use. More particularly, it is my object to provide a discharge device of the general character of a mercury pool tube, which is constructed and arranged to permit the existence within the device of potential differences of X-ray producing magnitude.

Briefly, this is accomplished by providing between the anode and the cathode of the device a constricted orifice of such dimensions as automatically to cause an abrupt interruption of the discharge and the consequent creation of high potential differences in the discharge circuit. I am aware that such self-produced interruption—which I shall call the "constriction effect"—has been used in other connections for the production of high frequency oscillations and the like. However, to the best of my knowledge the possibility of its use for the purpose of obtaining high voltages in X-ray producing devices has never been suggested.

The novel features which I desire to protect herein are pointed out with particularity in the appended claims. The invention itself together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the drawings in which Fig. 1 illustrates an X-ray apparatus suitably embodying the invention; Figs. 2 and 3 are graphical representations useful in explaining the invention; and Fig. 4 illustrates an alternative embodiment.

Referring particularly to Fig. 1 I have shown a discharge device comprising a sealed envelope 10 consisting of a glass cylinder which is closed at its lower end by means of a metallic header 11. This header is in contact with a mercury pool cathode 12 and supports a cooling coil 13 which serves during operation to limit the mercury vapor pressure.

Associated with the cathode there is provided a keep-alive electrode 14, suitably of graphite, which is adapted to maintain a holding arc to the cathode surface. In order to initiate such an arc there is provided an immersion ignitor of known type which functions when energized to produce a cathode spot on the mercury surface. A starting circuit comprising a current source 18 and a control switch 19 may be used to energize the electrode 16 when it is desired to start the tube in operation. The holding-arc cathode spot may be confined to a desired portion of the cathode surface by means of a ring 21 of cathode-spot-anchoring material, for example, molybdenum. A resistor 22 in series with the anode 14 serves to limit the holding-arc current to a desired value.

At the upper end of the tube there is provided an anode structure which is shown as comprising a heavy shaft portion 24 cooled by means of a fluid circulating system having an inlet 25 and an outlet 26. The anode terminates in a portion 28 which has a central opening 29 therein and which incorporates a discharge receiving member or target which is constituted of a material capable of effective X-ray emission when bombarded by high velocity electrons. Materials of high atomic weight are suitable for this use but I consider tungsten to be a preferred example because of its superior ability to withstand heat. The target 30 has its surface inclined to the axis of the tube so as to facilitate the projection of X-rays therefrom to a region outside of the tube. Such projection is further aided by the provision of a lateral opening 32 provided in the anode portion 28.

In accordance with my invention, means are provided for narrowly restricting a portion of the discharge path between the main anode and the cathode. In the present case such means is shown as comprising the combination of a heavy plate 35 having a central opening 36 therein and a lighter plate 39, positioned over the opening 36 and itself having an opening 40 of relatively small diameter, preferably from about one-quarter to one-half inch. In some cases, it is advantageous to provide in connection with the plate 35 a cooling means such as is indicated by the cooling coil 41 secured peripherally to the plate.

In operation, after the holding anode 14 is energized, a main discharge is initiated through the tube by applying to the principal electrodes a potential derived from a direct current source 42. This source need have only a relatively small voltage, say several hundred volts, and is connected across the tube through a circuit which includes a current limiting resistance 43 and an inductance 44. In parallel with the tube and inductance there is provided a condenser 45 shunted by a voltmeter 46. A potential-limiting spark gap 47 is connected across the tube terminals in series with a resistance 48. An ammeter 49 is provided for measuring the current supplied to the tube.

As current begins to flow through the tube the initial discharge may take the form of an arc discharge having a relatively low potential drop. Under these conditions the current starts to build up approximately linearly as indicated by the portion A of the graphical representation of Fig. 2. Its rate of increase is limited primarily by the inductance 44. As soon as a certain critical value B of current is attained, however, the tube suddenly ceases to be normally conductive so that the current decreases abruptly as indicated at C.

While I do not wish to be limited to any particular theoretical explanation of this result, a possible explanation is as follows: As the current through the opening 40 increases, the ions and electrons which are respectively moving toward the cathode and anode sweep all the gas or vapor molecules out of the opening. Under these conditions, the further maintenance of a discharge having arc-like characteristics is impossible. Such current as persists through the opening must be electron current and, therefore, assumes the characteristics of a pure electron discharge. As a result, it is possible for high potentials to exist across the opening 40.

With circuit connections such as those shown, if the inductance 44 is of sufficiently high value, a potential of X-ray producing magnitude may be developed within the tube by the mechanism described. This is a result of the voltage which builds up across the inductance 44 due to the sudden decrease in discharge current occurring at C (see Fig. 2). The voltage variation referred to is indicated by the curve of Fig. 3 which is correlated on the horizontal axis with the current curve of Fig. 2. It will be seen that at the point B the voltage across the inductance 44, and consequently that applied to the discharge tube, rises suddenly to extremely high proportions.

During the existence of the high potential gradients produced within the tube by the voltage developed across the inductance 44, such electrons as are to be found in the vicinity of the opening 40 may be accelerated toward the anode with high velocity. Impinging on the target 32, they cause the emission of X-rays therefrom, certain of such rays being projected laterally through the opening 32 to a region outside the tube.

In order properly to confine the ionization produced by the high velocity electrons in the vicinity of the anode, there are provided shielding members 52 and 53. An additional shielding member 54 serves to protect the sealed joint between the envelope and the plate 35 from high potential gradients which might otherwise cause puncturing of the tube at this point.

Somewhat higher voltage operation can be obtained by utilizing an arrangement in which a plurality of constricting barriers are provided in series. Such a construction is shown in Fig. 4 in which parts corresponding in function to elements already described are identified by similar numerals. In this case, however, there is provided between the target 30 and the cathode pool 12 a series of annular rings numbered 60, 61, and 62 respectively. These are supported by being tightly fitted to the interior of the envelope and are so disposed that their central apertures (numbered 64, 65 and 66) correspond with the normal discharge path. With this arrangement the operation of the device is substantially the same as that explained in connection with the construction of Fig. 1. The presence of a number of constricting orifices in series, however, makes it possible for the device as a whole to sustain materially higher voltage than is possible with a single opening.

While I have in the foregoing referred particularly to a cathode of the mercury pool type, the invention is equally applicable in connection with the thermionic or other cathodes where a substantial quantity of an ionizable medium is provided in the discharge space. Such medium may comprise a fixed gas (rather than mercury vapor as in the construction above described) or it may comprise a mixture of a gas and a vapor.

In the case of mercury, the mercury vapor pressure is preferably maintained in the range of from a fraction of a micron to several microns. On the other hand, for a fixed gas such as neon, the equivalent pressure will be many times higher. In any case the appropriate pressure will be at least from 10 to 100 times higher than the pressure considered appropriate in the old style cold cathode gas-containing X-ray tubes. Such tubes would be entirely inoperative if supplied with gas or vapor at the pressures utilized in the tubes of my present invention.

Furthermore, while I have described my invention in connection with a single embodiment thereof, it should be understood that numerous modifications may be made by those skilled in the art without departing from the invention. I, therefore, aim in the appended claims to cover all such equivalent variations as fall within the true scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An X-ray producing device comprising an envelope enclosing a readily ionizable medium at a pressure sufficient to support an arc discharge, an anode and a cathode within the envelope, said anode having at least a portion of its discharge-receiving surface constituted of a material which is an effective X-ray emitter when bombarded by high potential electrons, and means narrowly confining a portion of the discharge path between the anode and cathode, whereby X-ray producing potentials may be developed within the tube as a result of a constriction effect occurring during the passage of a discharge therethrough.

2. An X-ray tube comprising a cathode, an anode, an ionizable operating medium at a pressure sufficient to support an arc discharge and means narrowly confining the discharge space between the anode and cathode whereby X-ray-producing potentials may be developed within the tube as a result of a constriction effect occurring during the passage of a discharge therethrough, the said anode having at least a portion of its discharge-receiving surface arranged to facilitate the projection of X-rays therefrom to a region outside the tube.

3. In combination, an anode capable of effective X-ray emission upon bombardment by

high velocity electrons, a mercury pool cathode, one or more barriers separating the anode and cathode, said barriers being provided with restricted openings to permit the passage of a discharge therethrough, and circuit means connecting with the anode and cathode, said circuit means including inductance of sufficient value to permit the development of an X-ray producing potential as a result of constriction effects occurring in said restricted opening during passage of discharge current therethrough.

4. An X-ray tube including a mercury pool cathode, means for maintaining a holding arc to the cathode surface, an anode having a tungsten discharge-receiving surface which is angularly inclined with respect to the axis of the tube to facilitate the projection of X-rays therefrom and a barrier separating the anode and cathode, said barrier having a restricted opening whereby an X-ray-producing potential may exist within the tube during a discharge period as a result of constriction effects ocurring in said opening.

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