

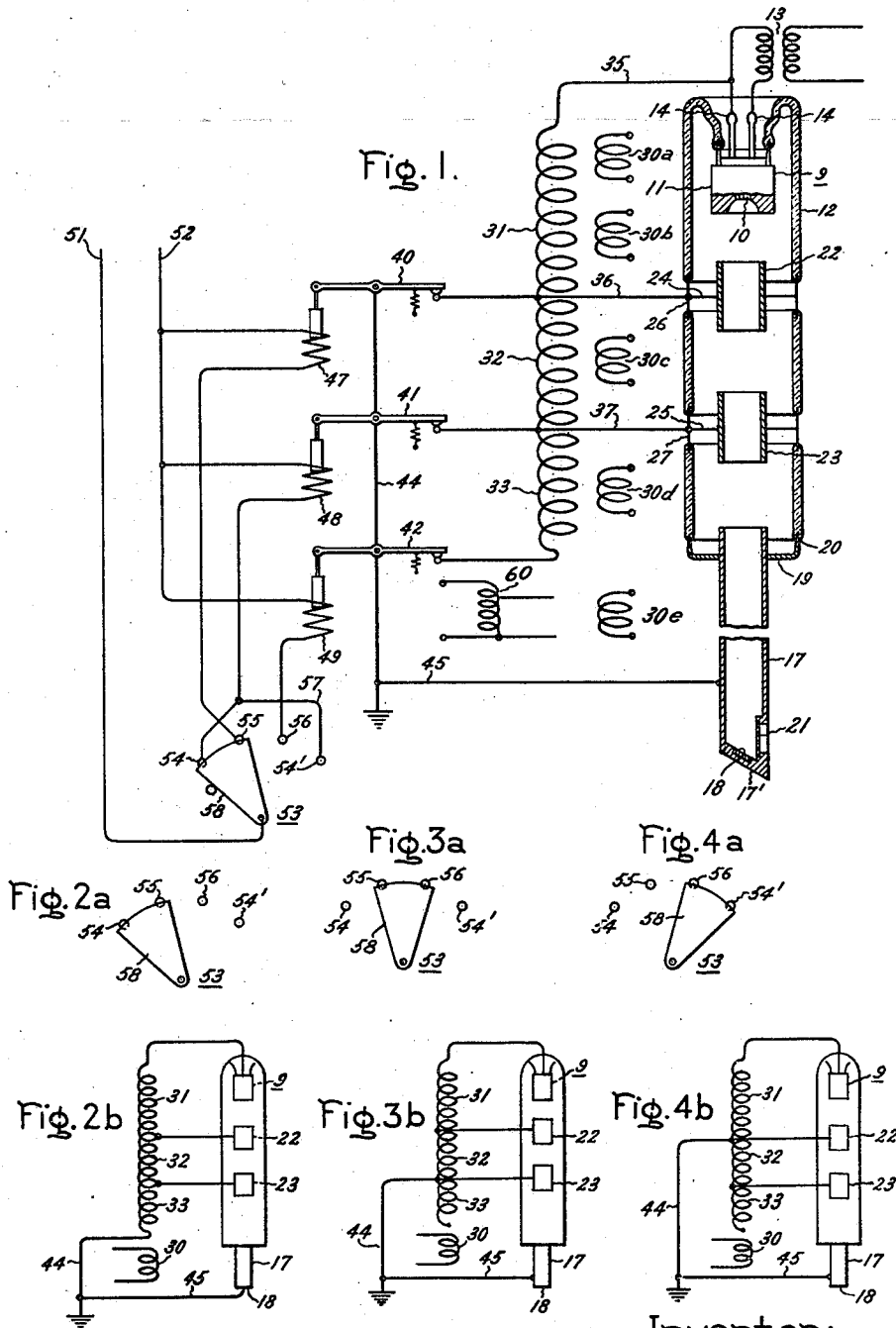
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RAY-GENERATING APPARATUS.

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RAY-GENERATING APPARATUS

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The present invention relates to ray-generating apparatus, such as X-ray equipment. It is a primary object of the invention to provide a ray-generating apparatus which is adapted to produce rays of different degrees of intensity and penetrating power.

While it is well known that the penetrating power of the rays generated by an X-ray apparatus can be varied by varying the potential impressed between the terminals of the tube, there are certain difficulties attendant upon this method of control which make its use inexpedient when a relatively large range of variation is desired. For example, in connection with an X-ray tube having a number of intermediate electrodes (as is characteristic of most tubes intended for very high voltage operation), diminishing the voltage impressed upon the various electrodes tends concurrently to reduce the current flowing through the tube. This reduction proceeds to an undesirable point if the range of voltage diminution is very great. The reduction in current is found to be attributable to the occurrence of excessive space charge in the first section of the tube as the voltage on that section is reduced below the optimum level.

My present invention is concerned with the provision of means by which the total acceleration of electrons proceeding from the cathode to the target of a multisection tube can be varied without concurrently reducing the electron current to the target to any appreciable degree.

An important feature of the invention consists in an arrangement by which, in the condition of the tube which corresponds to the highest operating voltage, the various electrodes of the tube, including the target, are at progressively increasing potentials with respect to the cathode. For obtaining rays of a lesser degree of penetration, however, provision is made for connecting the target optionally to lower voltage points of the power source than in the connection originally referred to without otherwise disturbing the connections of the intermediate electrodes. The manner in which this permits a reduction in the total electron acceleration will be explained more fully at a later point.

The features of the invention which I desire to protect herein are pointed out 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 drawing in which Fig. 1 is a schematic representation of an apparatus suitably embodying the invention;

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Fig. 2a illustrates the control switch for the apparatus of Fig. 1 in one of its operating conditions; Fig. 2b shows the circuit connections of the apparatus which correspond to the switch position of Fig. 2a; and Figs. 3a, 3b and 4a and 4b comprise similar representations with reference to other possible positions of the switch.

Referring particularly to Fig. 1, there is shown an X-ray tube of the multisection type. This comprises a cathode, designated as 9, which comprises the combination of a filamentary electron emitter 10 and a metallic focusing cup 11. The member 11 may be assumed to be connected to one terminal of the filament. The cathode structure 9 is hermetically sealed into one end of a glass part 12 which forms a portion of the envelope of the X-ray tube. Heating current from a transformer 13 is supplied to the filament through lead-in seals 14.

The other end of the tube comprises a target structure consisting of an elongated metal tube 17 terminating in an inclined metal end wall 17'. In the latter is embedded a target 18. The tube 17 is provided with a flange 19 by which it is hermetically sealed to the extremity of the tube envelope as indicated at 20. The side wall of the tube 17 may be provided with a window 21 made of material readily permeable to X-rays, as for example beryllium.

Between the cathode 9 and the target 18 there are provided a pair of intermediate electrodes 22 and 23 which are in the form of metallic tubes arranged in axial alignment. The electrodes 22 and 23 are respectively supported by metal webs or diaphragms 24 and 25 which connect with the terminal rings 26 and 27. These rings, which may be constituted of fernico or other metals suitable for sealing to glass, are fused into the glass wall structure of the tube envelope so as to provide a gas-tight unit. The envelope as a whole is highly evacuated by methods well known in the electronics art.

For the purpose of energizing the tube described in the foregoing there is provided a transformer having primary windings represented by the coils 30a, 30b, 30c, 30d and 30e. These coils 30a-30e may be connected in multiple by suitable conductors (not shown) to a source of alternating current which here is represented by the compensator coil 60 and attached conductors. The spacing of the parallel-connected primary coils 30a-30e longitudinally with respect to the secondary winding improves the magnetic linkage between primary and secondary coils, and avoids the distortion of wave shape which might

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occur if a single primary winding were located near one end of the secondary as indicated in the diagrammatic representation of Figs. 2b, 3b and 4b. A high voltage secondary winding is provided which is divided into three equal sections, these being respectively indicated at 31, 32 and 33. One end of this winding is connected directly to the cathode structure 9 as by a conductor 35 and intermediate terminals 36 and 37 provided at the respective junctions of the winding sections are connected by the conductors to the intermediate electrodes 22 and 23.

For the purpose of controlling the total acceleration of the electrons projected from the cathode 9 toward the target 18 (and consequently the degree of penetrability of the rays emitted from the target), there is provided, in connection with the transformer secondary winding, a controllable switching arrangement now to be described. This comprises a series of three independently operable switch elements 40, 41 and 42 which are all connected to a common grounding conductor 44, this latter conductor having a further connection with the target bearing tube 17 as indicated at 45. The switch element 40 is adapted when in its closed position to be connected to the terminal 36. The element 41 is similarly connected to the terminal 37 and the switch element 42 is connected when closed to the low voltage end of the secondary winding section 33.

The switch elements 40, 41 and 42 are all of the solenoid operating variety, being held closed when inactive by springs, as indicated in the drawing. Operating coils 47, 48 and 49 are provided in connection with the various switch elements. A power supply indicated by the parallel wires 51 and 52 is provided for the purpose of energizing the various switch solenoids and the manner of their energization is controlled by a multicontact switch designated as a whole by the numeral 53.

The switch 53 is provided with four contact terminals 54, 55, 56 and 54' having a particular order of arrangement as indicated, the fourth terminal being cross-connected to the first terminal by a jumper connection 57. The movable component of the switch 53 comprises a rotatable contact blade 58 which is adapted to bridge two and only two adjacent terminals. The first operating position of the switch 53 is illustrated in Fig. 2a. With this position of the switch it will be seen that power is supplied to the solenoid coils 47 and 48 so that the switch elements 40 and 41 are drawn into the open circuit position, switch element 42 remaining in closed circuit position.

Under these circumstances the effective connections of the X-ray tube are those indicated diagrammatically in Fig. 2b. In this figure, as well as in the Figs. 3b and 4b, the primary windings are indicated collectively as a winding 30 and, indeed, a single primary winding may be used in some cases. It will be seen from this figure that with the connections in question the maximum available voltage is impressed on the X-ray tube, the arrangement being such that the voltage level increases progressively as one proceeds from the cathode through the various intermediate electrodes toward the target 18. The X-ray tube is assumed to be self-rectifying so that current flow through it occurs only when the target or grounded end of the tube becomes positive with respect to the cathode. Under these circumstances the penetrability of the rays generated by the tube is a maximum. Assuming that the full voltage which can be supplied by

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the transformer is on the order of 250,000 volts, the connection of Fig. 2b permits the use of the tube for such purposes as therapy or in the industrial field for the examination of relatively thick metallic bodies, such as castings.

When any desired use of the tube is one which requires X-rays of less intensity and penetration, as, for example, in radiography and fluoroscopic examinations, the alternative connection established by the switch position of Fig. 3a may be employed. In this position the movable contact 53 bears upon the terminals 55 and 56, thus leading to energization of the coils 47 and 49 by which the switch elements 40 and 42 are brought to open circuit position, the switch element 41 remaining closed. This results in the circuit arrangement of Fig. 3b in which the secondary coil section 33 is seen to be effectively disconnected from the tube. It will be noted further that the target structure 17 is now connected directly to the intermediate electrode 23 so that its potential level corresponds to that of the electrode specified. Under these circumstances the total acceleration experienced by electrons proceeding from the cathode toward the target is only $\frac{2}{3}$ of that obtained with the connection of Fig. 2b (assuming equality of the various coil sections 31, 32 and 33). At the same time the potential conditions existing in the first and second sections of the X-ray tube have not been disturbed, the direct connections between the source of potential and the auxiliary electrodes 22 and 23 remaining intact, so that the space charge in the vicinity of the cathode is the same as in the previous case. Accordingly, the current in the tube may be maintained at the optimum value in spite of the fact that the effective operating voltage of the tube has been reduced.

Where a still lower effective voltage is desired, as in crystallography or in other connections in which relatively soft X-rays are desired, the third position of the switch 53 may be employed. This third switch position, which is illustrated in Fig. 4a, results in opening switches 41 and 42 while leaving the switch 40 closed, the resultant circuit connection being shown in Fig. 4b. As appears from this latter figure, the voltage impressed on the intermediate electrodes 22 and 23 is precisely the same as in Figs. 2b and 3b since the effective connection of these electrodes to the energizing transformer is not disturbed. However, the target 17 is now made equipotential with the electrode 22. The effect of this connection is as follows.

Electrons emitted from the cathode 9 are accelerated in the first section of the tube by an amount corresponding to the voltage impressed on this section (say 83,500 volts) and are further accelerated by an equal amount (i. e. to a total of 167,000 volts) by the voltage impressed on the second section of the tube. However, due to the connection of the target structure 17 to the electrode 22 the voltage encountered in the last section of the tube is of such direction as to decelerate the electrons rather than to produce further acceleration of them, this being obviously a result of the fact that the target has a lower potential difference than the electrode 23 with respect to the cathode. Accordingly, the electrons which have been brought to an equivalent voltage of 167,000 volts by the action of the second section of the tube are again reduced to an equivalent voltage of 83,500 volts by the retarding action which they experience in the last section of the tube. Accordingly, their velocity

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of impingement on the target 18 is relatively low so that the generation of soft X-rays is to be anticipated.

As in connection with Fig. 3b, the results obtainable with the connection of Fig. 4b are achieved without effecting the potential distribution in the first two sections of the tube. Accordingly, even in this case the current from the cathode 9 is not affected in any adverse sense.

It will be seen that the arrangement which has been described in the foregoing greatly increases the field of usefulness of a single tube and makes it an extremely flexible tool for use in connections where a variety of applications are anticipated. In addition, the invention decreases the number of different types of equipment which must be manufactured to satisfy the various demands of the trade.

A still further increase in flexibility may be obtained by providing some measure of voltage control in connection with the energizing transformer itself. For example, there may be provided in connection with the transformer primary 30 a control device in the form of an autotransformer 60 by which the voltage applied to the primary windings 30 may be varied within reasonable limits. While the range of variation which may be obtained by this means is limited by considerations which have previously been stated herein, the combination of this type of control with the switching arrangement which has been described assures a degree of flexibility equal to almost any probable demand.

While the invention has been described by reference to a particular embodiment thereof, it will be understood that numerous modifications may be made by those skilled in the art and I, therefore, aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

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

1. In combination, a ray-generating tube comprising a series of aligned electrodes including a target as the last electrode in the series, an energizing circuit for impressing potentials of increasing magnitude on the electrodes which are progressively more remote from the cathode, and means for varying the total acceleration of electrons projected between the cathode and target, said means comprising an arrangement for connecting the target to various potential points of said energizing means without changing the connections of the other electrodes thereto.

2. In combination, a ray-generating tube comprising a series of aligned electrodes including a target as the last electrode in the series, a power source which can be connected so as to impress potentials of increasing magnitude on the electrodes which are progressively more remote from the cathode, and means for varying the total acceleration of electrons projected between the cathode and target, said means comprising an

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arrangement for optionally making said target equipotential with the various ones of said intermediate electrodes while leaving intact the connections of said intermediate electrodes to said source.

3. The combination of an X-ray tube comprising a cathode, a target and spaced intermediate electrodes, circuit connections for impressing accelerating potentials on said electrodes including said target, and switching means for optionally rendering said target equipotential with respect to chosen intermediate electrodes while leaving intact said circuit connections to said electrodes, thereby varying the penetrability of the X-ray output.

4. In combination, a ray-generating tube comprising a cathode, a target spaced from said cathode, and a plurality of intermediate electrodes successively interposed between said cathode and target, means for establishing a positive potential difference between the cathode and the remaining electrodes, including the target, which increases successively as one proceeds from the cathode to the other electrodes in the direction of the target, and means for connecting the target to the first of said intermediate electrodes without changing the connections of said first electrode, thereby to diminish the total acceleration of electrons projected between the cathode and the target without appreciably changing the current flow through the tube.

5. An X-ray apparatus comprising the combination of an X-ray tube containing a series of linearly arranged electrodes, one of which is an electron-receiving electrode, a transformer including a plurality of secondary windings direct conductive connections from said windings to said electrodes, a plurality of primary windings which are inductively coupled to said secondary windings and linearly arranged with respect thereto, a circuit containing switches for optionally connecting said electron-receiving electrode to selected terminals of said secondary windings without disturbing the connections thereto of said intermediate electrodes in said series of electrodes.

6. The combination of an X-ray tube comprising an elongated evacuated envelope having mounted therein a series of electrodes therein including a main cathode, an X-ray target and intermediate auxiliary electrodes, a source of energy, conductors directly connecting each of said electrodes to different terminals of said source, said conductors being arranged to impose successively increasing potential differences between said cathode and the successive electrodes of said series and switching means for optionally transferring the connection of one of said main electrodes from one terminal of said source to another while leaving intact the connections of said auxiliary electrodes to said source.

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