

Aug. 13, 1935.

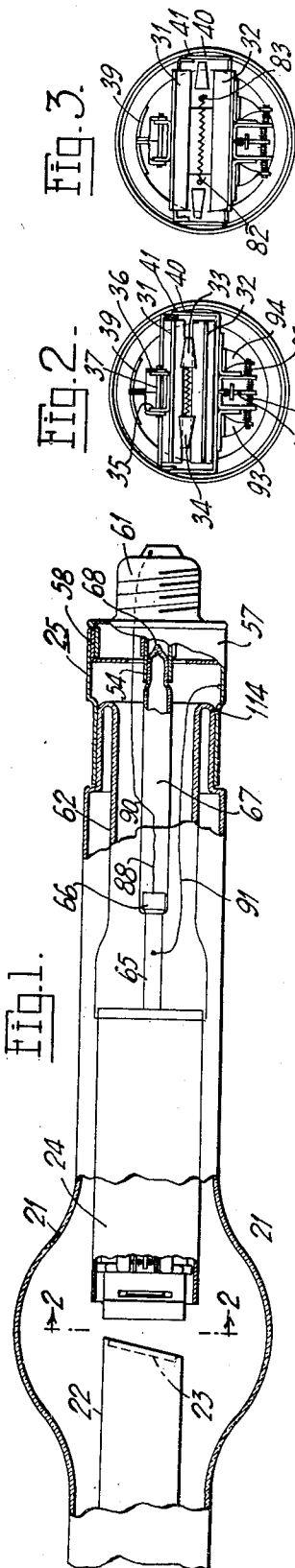
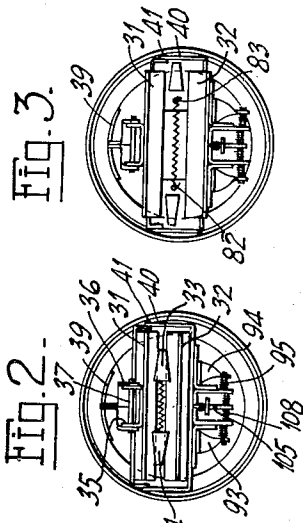
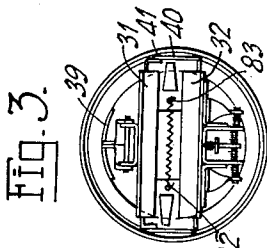
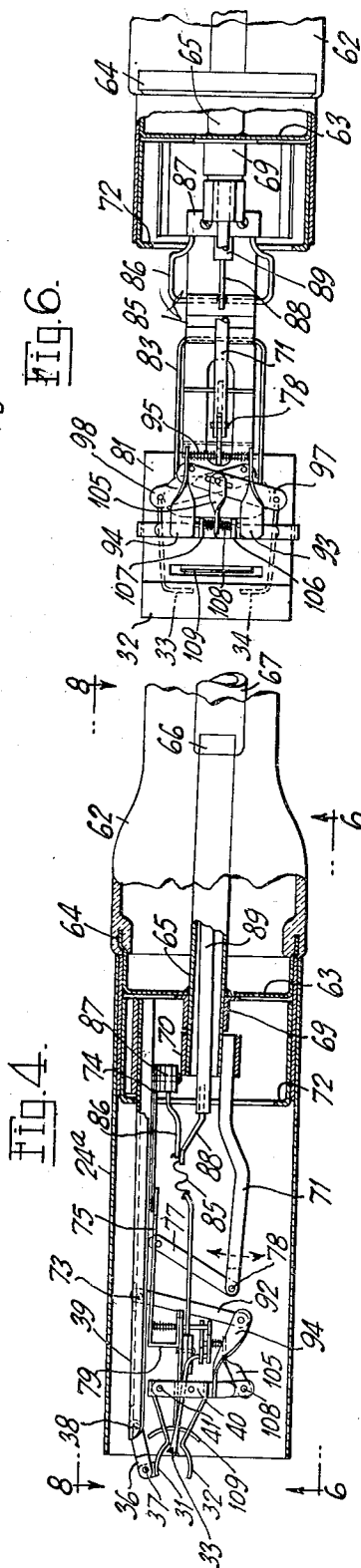
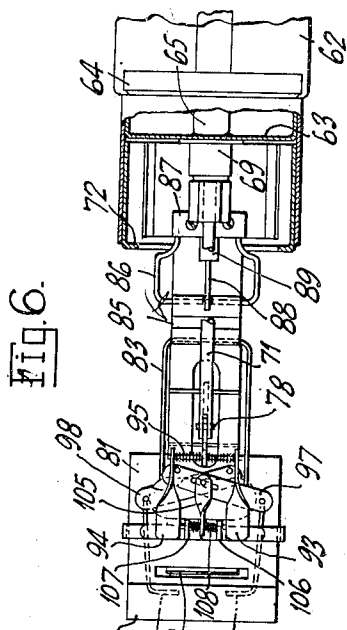
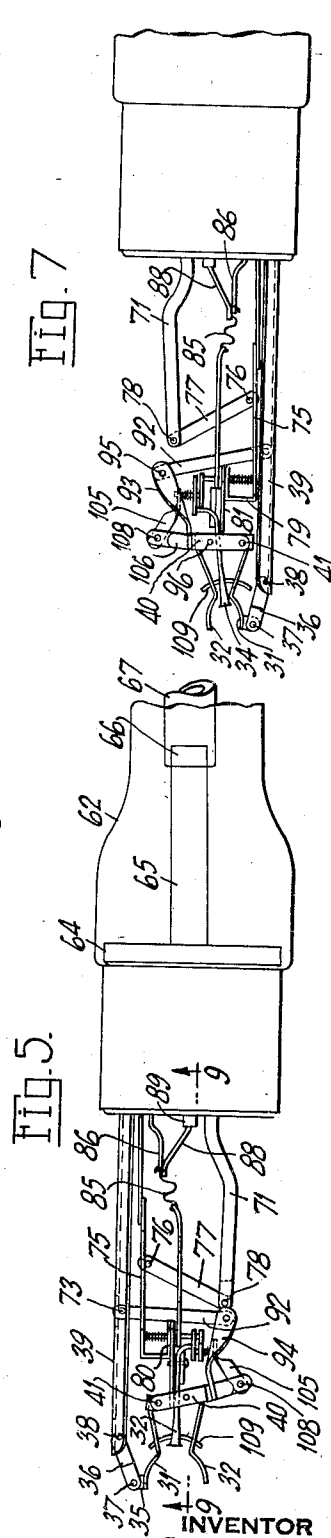
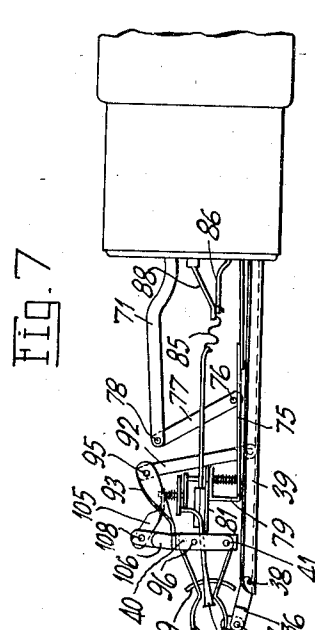
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2,011,540

X-RAY TUBE

Filed April 18, 1934

4 Sheets-Sheet 1



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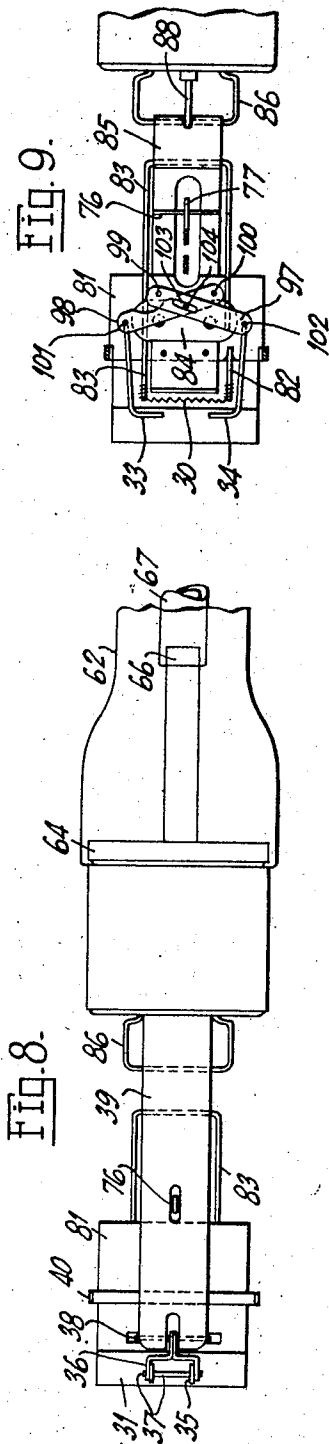
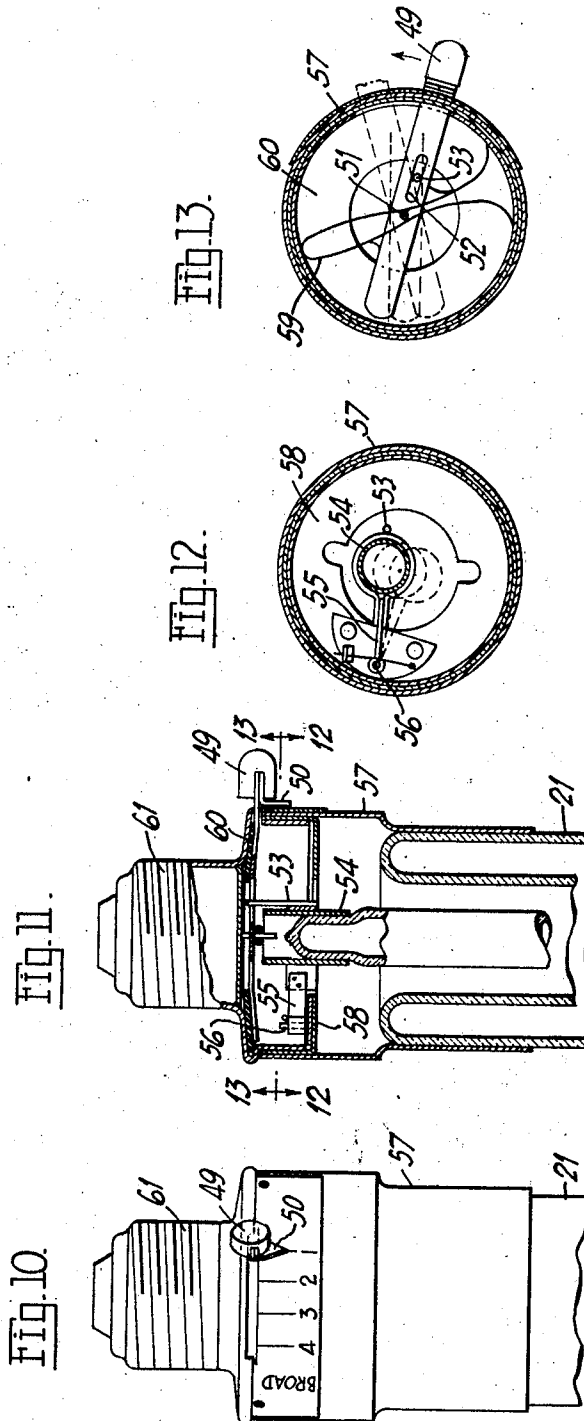
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X-RAY TUBE

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4 Sheets-Sheet 2



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X-RAY TUBE

Filed April 18, 1934

4 Sheets-Sheet 3

Fig. 14.

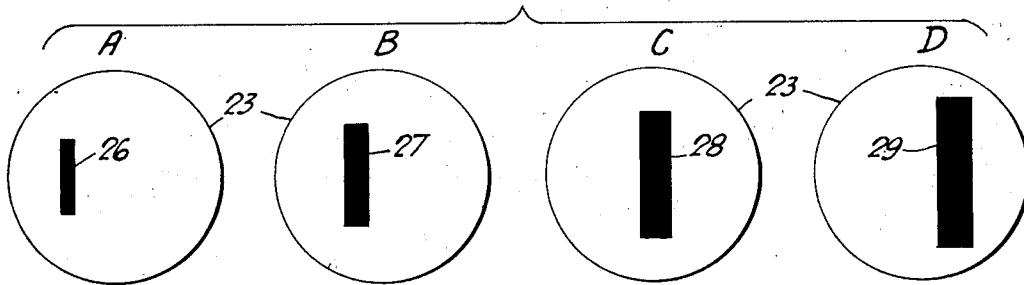


Fig. 15.

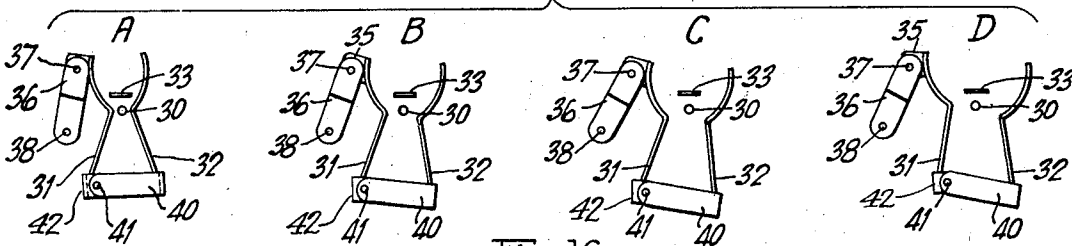


Fig. 16.

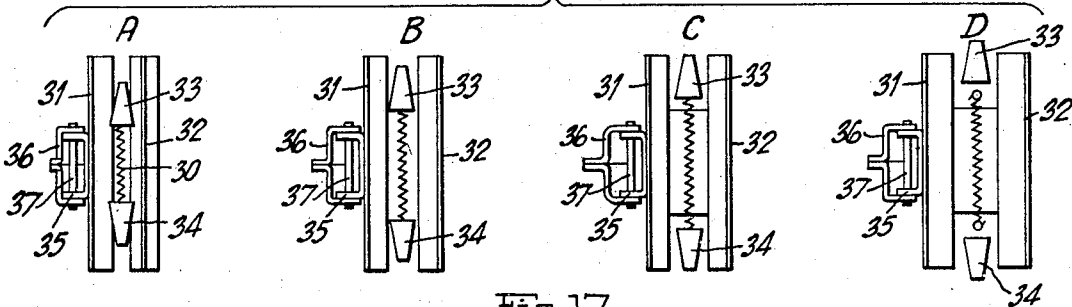
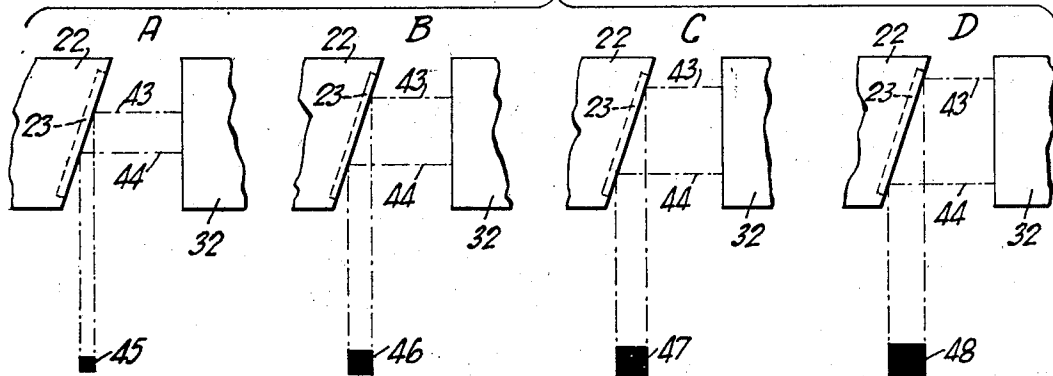


Fig. 17.



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4 Sheets-Sheet 4

Fig. 18.

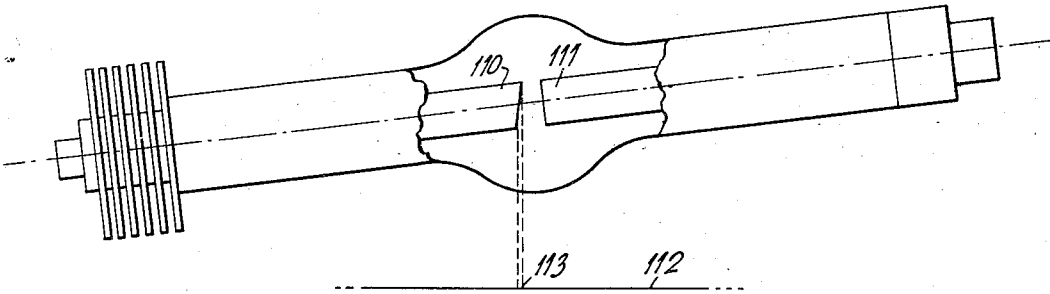


Fig. 19.

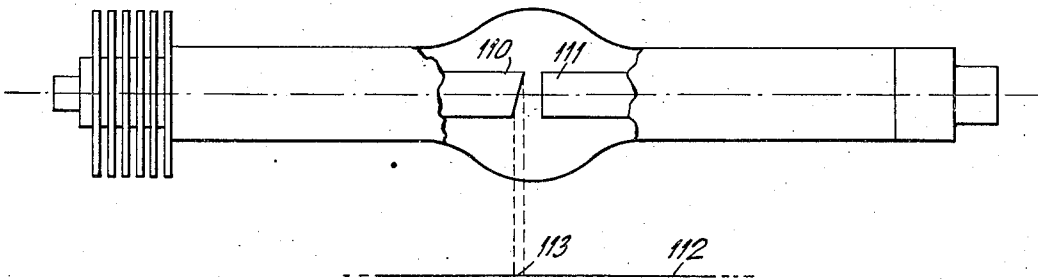
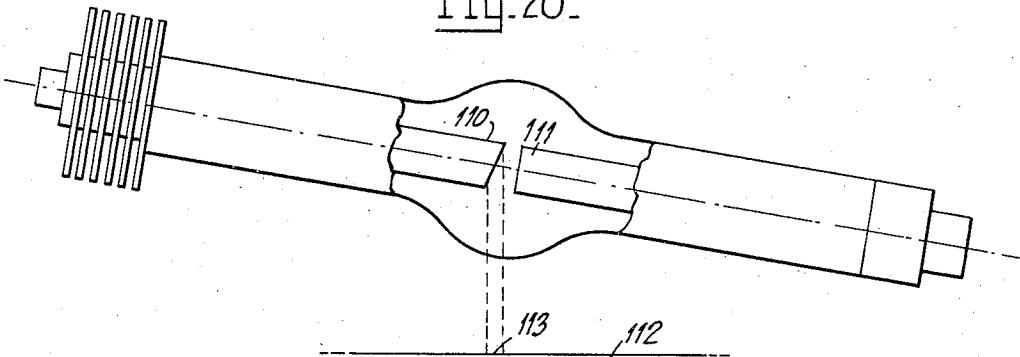


Fig. 20.



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UNITED STATES PATENT OFFICE

2,011,540

X-RAY TUBE

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Application April 18, 1934, Serial No. 721,142

36 Claims. (Cl. 250—35)

This invention pertains to X-ray tubes and has to do more especially with adjustable focus tubes—particularly those of the line-focus variety. In certain aspects, however, its scope is not confined to adjustable focus tubes nor to line focus tubes but, on the contrary, embraces fixed focus as well as non-linear focus tubes.

There are several underlying objects of the invention, chief among which are: (1) to provide an adjustable line-focus tube having means whereby several sizes of focal spot are rendered available—ranging from fine to broad—the size of the spot being under the control and subject to the will of the operator; (2) to provide an X-ray tube wherein the focal spot is movable to different parts of the target surface—especially an adjustably variable line-focus tube in which the different sized spots occupy different parts of the target face and (3) to provide an adjustable-focus tube having an adjusting mechanism which is positive in action, adequately rugged and reliable and capable of being manufactured economically; more especially, a line-focus tube of that character.

Classified according to configuration of focal spot X-ray tubes are of two general varieties, namely: "round focus" and "line focus" respectively. A suitable definition of a round focus tube is: "one in which the hot spot or focal spot on the target produced by the electron stream is of a generally circular form". Its contour may, however, be far from truly circular. An appropriate definition of a line-focus tube is: "one in which the hot spot or focal spot is, in general, of elongated rectangular form—that is, long and narrow. Such a spot is not really linear in the true geometrical sense because it has breadth as well as length; but, in keeping with actual commercial terminology, it will be referred to in this specification as a "linear spot".

Another classification of X-ray tubes appropriate to mention preliminarily to the description and dissertation upon the present invention which is to follow is: "fixed focus" and "adjustably variable focus" respectively. The conventional single focus tube, whether of the round or line-focus variety, wherein the size of the focal spot is constant or substantially so, is what is here referred to as a "fixed focus" tube. With such a tube the operator has no control over the size of the focal spot. An adjustably variable focus X-ray tube is one in which some provision is made whereby the size of the focal spot can be altered under the control of and at the will of the operator. This latter definition does not em-

brace any case in which the size of the focal spot may vary automatically in response to the occurrence of some determinative or abnormal condition. Nor does the term "adjustably variable" or any of its derivatives include any tube structure wherein an adjustment of the size of the focal spot can be effected by taking the tube apart and destroying its vacuum.

There are two types of X-ray tubes having adjustably variable focal spots. One of these is the multiple or two-filament tube with which a choice of two focal spots is available by utilizing one or the other of the filaments. It is not practicable to employ more than two filaments; but two sizes of focal spot are not enough to meet all requirements. That, in few words summarizes the deficiency of the multiple filament type tube.

The alternative type of adjustably variable focus X-ray tube is that illustrated in my co-pending application, Serial Number 557,982, filed August 19, 1931, entitled "Variable focus X-ray tube" wherein the area of the focal spot is rendered variable by making the focusing cup or shield movable relatively to the cathode—thereby altering the focal distance and consequently the size of the spot.

The adjustably variable focus tubes shown in my above identified co-pending application are of the round focus type whereas the present application deals more especially—though not exclusively—with line-focus tubes.

In order to achieve adjustability of the focal spot in a line-focus tube it is essential to provide means operable to vary the width of the linear spot on the target together with means operable at the same time to vary proportionately the actual length or the apparent length of the focal spot from the viewpoint of the subject. By the "subject" is meant that through which the X-rays are to be propagated; and the desideratum is a focal spot from the point of view of the subject which is as nearly equidimensional from its center as is possible to obtain. In speaking of the "apparent length" of the focal spot what is meant is its projected length from the viewpoint of the subject—it being remembered that the subject views the target of a line focus tube at an acute angle.

There are two possible ways of varying the apparent or projected length of a linear focal spot—both being within the purview of the present invention. One consists in altering its actual length as measured in the plane of the target surface and the other in changing the angularity of the target with respect to the subject. The latter can

be accomplished by effecting a change in the angularity of the tube with respect to the subject or vice versa; but I prefer the former method as being generally more suitable in practice because it entails but a single adjustment. The second mentioned method, however, has the advantage of simplifying the tube structure somewhat and to that extent reducing its cost. The tube which has been selected for detailed illustration is of the type in which the actual length as well as the breadth of the focal-spot is variable; but it will be apparent to those skilled in the art that the actual length of the spot can be made constant by omitting the provision whereby it is rendered variable, without interfering with the means for varying the breadth of the spot.

As is well known, the best radiographic definition is obtainable with a fine focal-spot because such a spot produces the least penumbra; but in many instances a satisfactory exposure cannot be obtained with a fine focal spot without resorting to a dangerously high space amperage—that is to say, dangerous from the point of view of pitting the target. This often leads in critical cases, to the operator taking chances upon over-loading the tube and results only too frequently in destroying its further usefulness. For the foregoing reason I conceive it to be highly desirable to so design and construct X-ray tubes that the focal spot is movable to different parts of the target surface, so that if the target becomes impaired in part the tube is not thereby rendered useless. Obviously, that aspect of my present invention applies both to fixed-focus and variable focus tubes and, likewise, to both round and linear focal spots—that is, without regard to the shape of the focal spot. The present application is, as previously announced, directed more specifically, of course, to adjustably variable line-focus tubes and, for that reason, the structure illustrated is one in which the differently placed focal spots are linear in form and of a variety of sizes; but, if desired, the size of the spot could be fixed while at the same time it is movable over the face of the target. And such an alternative is distinctly advantageous in cases where only one size of focal spot is needed.

Inasmuch as the present invention is believed to be broadly novel and therefore to embrace within its scope a wide range of equivalents, it seems neither practicable nor prudent to attempt to state at this point its novel features and combinations, but these are adequately pointed out in the following detailed description and defined in the appended claims.

In the drawings which accompany this specification,

Fig. 1 is a small scale fragmentary view, partly in section and partly in elevation, of an adjustably variable focus line-focus X-ray tube. In this view the anode terminal end of the tube, which may be of conventional design, has been omitted to conserve space, being not essential to a complete disclosure of the invention;

Fig. 2 is a view of the cathode head taken along the line 2—2 of Fig. 1 with the tube adjusted to produce a fine focal spot;

Fig. 3 is identical with Fig. 2 except that here the tube is adjusted to produce a broad focal spot;

Fig. 4 is a longitudinal view, partly in section and partly in elevation, of the cathode head—adjusted to produce a fine focal spot;

Fig. 5 is an elevational view of the cathode head, similar to Fig. 4 except that the metal cover is

omitted and the adjustment is for a broad focal spot;

Fig. 6 is an elevational view of the cathode head taken along the line 6—6 of Fig. 4—the metal cover being omitted as in Fig. 5;

Fig. 7 is an elevational view of the cathode head adjusted for fine focus and viewed from the far side of Fig. 4;

Fig. 8 is a rear elevational view of the cathode head taken along the line 8—8 of Fig. 4—the cover being also omitted in this instance;

Fig. 9 is an irregular sectional view taken approximately along the line 9—9 of Fig. 5;

Fig. 10 is an elevational view of the cathode-terminal end of the tube including a screw base designed for connection to an electrical socket and a part of the focus adjusting mechanism;

Fig. 11 is a longitudinal sectional view of the cathode-terminal end of the tube;

Fig. 12 is a cross-sectional view taken along the line 12—12 of Fig. 11;

Fig. 13 is a cross-sectional view taken along the line 13—13 of Fig. 11—this view being complementary to Fig. 12;

Fig. 14 is a series of four views A, B, C and D respectively, looking toward the face of the target and illustrating a series of four different sized linear focal spots ranging from fine to broad. This figure serves also to illustrate the placing of the focal spots on different portions of the target surface;

Fig. 15 is a series of four side elevational views illustrating the operation of the focusing shields and showing their approximate positions with respect to the filamentary linear cathode and to each other for the several focal spot adjustments illustrated in Fig. 14. This figure also depicts the lateral movement of the cathode which occurs simultaneously with the movements of the focusing shields. It is to be observed that A, B, C and D of Fig. 14 correspond respectively with A, B, C and D of Fig. 15;

Fig. 16 is a series of four front elevational views (looking from the target) of the filamentary linear cathode and associated focusing elements. These are shown in the different positions of adjustment corresponding respectively with the side elevational views A, B, C and D of Fig. 15;

Fig. 17 is a series of four side elevational views showing in each case the target end of the anode and an indication of the adjacent end of the cathode head. These views correspond with the similarly lettered views of Figs. 14, 15 and 16 and their purpose is to illustrate the apparent, that is, projected focal spots and their relation to the actual focal spots shown in Fig. 14;

Fig. 18 is an elevational view of a line focus tube in which the focal spot is adjustable laterally only, set at an angle to produce a fine apparent focal spot—the tube having been adjusted to produce a narrow actual focal spot;

Fig. 19 is a view similar to Fig. 18 but with the tube adjusted to produce a medium apparent focal spot, and;

Fig. 20 is a view similar to Figs. 18 and 19 but with the tube adjusted to produce a broad apparent focal spot.

It will be helpful to an understanding of the tube structure illustrated and now about to be described, to have clearly in mind the major functions to be performed. These are: (1) to produce a linear focal-spot which is variable both as to length and breadth but with respect to which the proportionality between length and breadth is preferably constant; (2) to provide for

directing the electron stream or beam to different parts of the target face simultaneously with the variation of area of the focal spot; (3) to provide for positive actuation of the focusing and beam directing means; (4) to do this without impairing or risking any impairment of the vacuum and; (5) to provide a visual indication of the size of the focal spot and position thereof on the target or either of those things. Means to all these ends are incorporated in the present structure, but it should be kept in mind that not all are indispensable to an operative embodiment of this invention. For example, it is not at all essential to the success of the invention as a variable line-focus tube that the focal spot be movable to different parts of the target face, and it is likewise not essential to the movable focal spot feature that the size of the focal spot be variable. Nor is it an indispensable feature of the invention that a visual indicator be provided or that the actuating mechanism be positive in character. These several features all contribute to a common result, but each is useful and meritorious apart from the others; and that such is the case should be kept constantly in mind.

The tube is illustrated as a whole in Fig. 1, except that the anode-terminal end has been broken off—the omitted portion being of any well known conventional form. This figure serves to show the space relation between the principal parts of the structure. These principal parts are an evacuated glass envelope 21—the degree of vacuum being very high so that the tube will operate in the manner of a Coolidge tube by reason of substantially pure electronic emission without substantial ionization, an anode 22 having a tungsten target 23 inserted in its face, a cathode head 24 and a cathode-terminal end portion 25.

The cathode head 24 includes a tubular metallic cover 24a and a linear filamentary electron-emissive cathode 30 together with adjustable focusing elements or shields for concentrating the electron stream into a beam directed at the target and a mechanism for effecting adjustments of the focusing elements to vary the size of the focal spot and changing its position on the target—all under the control and subject to the will of the operator.

The cathode-terminal end portion 25 includes a screw base for effecting electrical connections with the cathode and a part of the focus adjusting and directing mechanism together with a visual indicator by means of which the operator can determine the setting of the tube.

Electrically, the tube is of conventional form in that the filamentary cathode is heated to incandescence by a current from a low voltage source and a high voltage is applied between the cathode and anode terminals—positive potential being applied to the anode terminal and negative to the cathode terminal. This results as usual in a stream of electrons being emitted by the hot cathode—which electrons flow through the intervening evacuated space to the target—the electron stream being focused upon a predetermined restricted portion or area of the target. This portion or area upon which the electron stream impinges is known as the focal spot.

Fig. 14 comprises a series of four views A, B, C and D respectively of the target face and illustrates four "linear" focal spots 26, 27, 28, and 29. View A depicts a fine focal spot 26 while view D depicts a broad focal spot 29. Spots 27 and 28 shown in views B and C respectively

are intermediate in size. The several focal spots shown in Fig. 14, it will be observed, occupy adjacent but distinctly separate portions of the target face which, as stated at the outset, is one of the novel features of this invention. It will be seen that the ratio of length to breadth of the spot as measured on the face of the target is constant. The focal spot, of course, becomes exceedingly hot during operation of the tube and, as previously explained, it is a rather frequent occurrence on this account for a target to become so badly pitted at the focal spot as to render the tube useless. Obviously, if any one portion of the target in the present case becomes excessively pitted the usefulness of the tube is not necessarily destroyed. In fact, the tube would still be useful if all but one of the focal spot areas were so impaired. Of course a tube can be so badly abused in a single operation as to wreck the entire target area but that does not often happen and could hardly occur except through intent or gross negligence.

To obtain a series of linear focal spots such as illustrated in Fig. 14 it is necessary to provide focusing means operable both laterally and longitudinally to concentrate the stream of electrons emitted by the cathode into a beam of linear cross-section; but as will be explained with reference to Figs. 18, 19 and 20 much the same ultimate result can be obtained by varying the breadth of the focal spot and leaving its length constant. But in the tube structure selected for illustration both the breadth and length of the spot are varied, and the immediate means for accomplishing that result are illustrated in Figs. 15 and 16—the adjusting mechanism as a whole, however, being shown in other figures of the drawings.

Illustrated in the several views of Figs. 15 and 16 are the filamentary linear cathode 30, a pair of complementary lateral focusing elements or shields 31 and 32, respectively, a pair of complementary longitudinal focusing elements or shields 33 and 34, respectively, a bifurcated lug 35 attached to element 31 and a bifurcated link 36, pivotally connected to lug 35 through the medium of a fulcrum pin 37. Link 36 is pivoted at 38 to a fixed stanchion 39—not shown in Figs. 15 or 16, but in several of the other figures. A U-shaped strap 40 is rigidly connected (welded) to focusing element 32 and pivotally connected at two corresponding points 41 to a similar U-shaped strap 42 which, in turn, is welded to focusing element 31. Pivot 41 forms a center about which elements 31 and 32 rotate relatively while at the same time the pivotal center 41, in company with cathode 30, moves laterally with respect to the longitudinal center line of the tube. This movement is also lateral of the direction of propagation of the beam of electrons emitted by the cathode and impinging upon the target to form the focal spot. The extreme and two intermediate positions of the focusing elements are well illustrated in the several views of Figs. 15 and 16. It will be observed that by drawing together the four focusing elements, the focal spot is both shortened and narrowed and, vice versa, by spreading the focusing elements the focal spot is lengthened and broadened. At the same time, the mechanical arrangement is such as to bring about a movement of the focusing elements and cathode causing the electron stream to be directed successively to different parts of the target face.

It will be observed that the cathode maintains an approximately centralized position at all times with respect to the lateral focusing elements. The action described is somewhat analogous to that of an adjustable focus flash light wherein the spread of the beam can be changed while at the same time the beam can be directed at different objects successively.

While Fig. 14 depicts the actual focal spots, Fig. 17 depicts correspondingly, what has heretofore been denominated the "apparent" or projected focal spots—that is, the focal spots as seen from the viewpoint of the subject—the subject being that which is to be radiographed. In each of the four views A, B, C and D of Fig. 17 there is shown the working end of the anode 22 with its tungsten target 23 and one of the focusing elements 32 in back of which, but not shown, is the linear hot cathode 30. Dot and dash lines 43, 44 represent the outline of the electron stream proceeding from the cathode to the target. X-rays are propagated from the target in all directions in which they are free to move and their effect upon a photographic plate is the same as that of light. Thus, as in the case of light rays, the smaller the area from which the X-rays emanate the less will be the ghost effect or penumbra. But there is little if any advantage to be gained by reducing the focal spot in one direction and leaving it unreduced in another, or in having a long and narrow focal spot unless, from the viewpoint of the subject, the effect or appearance of a substantially equidimensional spot can be brought about. That result is achieved in the tubes of the present invention as in all line-focus tubes by disposing the face of the target at an acute angle to the line of X-ray propagation through the subject to be radiographed. The apparent focal spots thus obtained are approximately square and of side dimension equal to the width of the actual focal spot. Four such apparent focal spots are illustrated in Fig. 17 at 45, 46, 47 and 48 respectively.

The mechanism whereby the operator is enabled to bring about the focus adjusting movements of the cathode and focusing elements is illustrated in detail in Figs. 2 to 13 inclusive. It is somewhat complicated in appearance because of the crowding together and smallness of the several parts and is difficult to illustrate adequately—for which reason it has seemed expedient to show numerous views. However, with a clear understanding of the functions to be performed and the movements of the cathode and focusing elements to be brought about, it should not be overly difficult to apprehend the actuating mechanism itself.

Focus adjustments and, at the same time, the movements of the focal spot across the target are accomplished by the operator moving a finger-operated lever 49. See Figs. 10, 11 and 13. This lever carries a pointer 50 in registration with a calibrated scale shown in Fig. 10, the readings of which indicate the size of the focal spot to which the tube happens to be adjusted. It also serves as an indication of the position of the focal spot on the target—an important consideration in a tube having a focal spot of fixed size when one or more of the target areas has become excessively pitted. Lever 49 is fulcrumed at 51 (see Fig. 13) on the longitudinal axis of the tube and it has an elongated slot 52 engaging a pin 53 connected to a tubular member 54 carried on the free end of an arm 55 which is fulcrumed at 56

(see Figs. 11 and 12). Tubular member 54 moves in an arc laterally of the major axis of the tube as indicated in dotted lines in Fig. 12.

The cathode-terminal end portion of the tube illustrated more particularly in Figs. 10 to 13 inclusive and designated as a whole by reference numeral 25 (see Fig. 1) includes, in addition to the mechanical parts just described, a cylindrical metal shell 57, a cup-shaped member 58 upon which arm 55 is pivotally mounted, a hairpin-shaped wire spring 59 which serves to hold lever 49 in place, a flat annular fiber washer 60 which functions as a lateral support and friction member against which lever 49 is pressed by spring 59, and a screw plug 61 adapted for insertion into an electrical screw socket. The cathode heating circuit is completed through screw plug 61. The frictional engagement between lever 49 and fiber washer 60 serves to retain the adjusting mechanism in any position of adjustment in which it may be set. Cylindrical metal shell 57 fits over the end of the glass envelope 21 as shown in Figs. 1 and 11.

Now the procedure is to convert the lateral arcuate movements of tubular member 54 into the focusing and beam directing movements of the cathode and focusing elements heretofore described with reference to Figs. 15 and 16; and to do so without impairing the vacuum within the envelope. The mechanism for accomplishing that objective is all included within what is here denominated the cathode head—designated as a whole by reference numeral 24. The cathode head is a unitary self-contained assemblage and is mounted upon and carried by a re-entrant glass sleeve or stem 62 which, upon completion of the tube, forms an integral part of envelope 21. One of the outstanding features of the cathode head is a cup-shaped flexible metal diaphragm 63 which is sealed at 64 (see Fig. 4) to the re-entrant stem 62. This diaphragm functions as a closure for the aperture extending axially through stem 62 and serves to maintain the vacuum in the envelope while at the same time permitting a positive transmission of mechanical motion from the outside to the inside thereof.

Extending axially through the center of diaphragm 63 and welded thereto is a metal tube 65 to the outward end of which is sealed at 66 a glass tube 67. Tube 65 and its extension 67 serve as a convenient medium for evacuating the envelope, being sealed off at 68 (see Figs. 1 and 11). The free end of tube 67 engages tubular member 54 and moves therewith in the arcuate path indicated in Fig. 12. The motion thus imparted to glass tube 67 is, in turn, imparted to metal tube 65 which is thereby caused to oscillate about the center of diaphragm 63 as a pivotal point or fulcrum. It will be evident that a corresponding oscillatory movement is imparted to the short end of tube 65 on the vacuum side of the diaphragm.

It has been mentioned that the path of tubular member 54 and, therefore, of the free end of glass tube 67 is arcuate, but that is a merely incidental fact. There is no advantage flowing from its being arcuate except that it works out conveniently that way. The reader should not be misled into supposing that the arcuate form of the path has some functional significance. It has not. It could just as well be straight so far as the mechanism about to be considered is concerned.

At the juncture of diaphragm 63 and tube 65 is a flanged tubular metallic member 69 through which tube 65 projects. This is merely a rein-

forcing element which facilitates welding the thin diaphragm to tube 65 and strengthens the joint therebetween. It would be difficult to make a durable vacuum-tight welded connection to the diaphragm without the reinforcing member 69.

Attached to the free end of the short arm of tube 65 is a sleeve 70 carrying an extension arm 71 which, of course, moves with tube 65 in response to manipulation of lever 49. The oscillatory movement of this extension arm is as indicated by a double headed arrow on Fig. 4.

Encircling and welded to the flange portion of diaphragm 63 is a cup-shaped metallic member 72 which serves as a rigid supporting member for stanchion 39. The latter is rigidly secured to member 72 and functions as a fixed support for pivotal connections 38 and 73.

Fixedly secured at 74 is a thin flexible metallic strip 75 to which is pivotally connected at 76 a link 77 which, in turn, is pivotally connected at 78 to the free end of arm 71. The action of flexible strip 75 in response to movements of arm 71 may be seen by comparative examination of Figs. 4 and 5.

The free end of flexible strip 75 is bent as indicated at 79, thus forming a flange 80 to which is welded a rectangular metal plate 81 (shown most clearly in Figs. 6 and 9). This plate serves as a mounting for various parts. To it are attached, among other parts, the supporting wires 82 and 83 for the linear filamentary cathode 30 (see Fig. 9). Wire 82 functions not only as a support for the cathode but also as a conductor for the cathode heating current and it is welded directly to the mounting plate 81 which is included in one side of the cathode heating circuit. Wire 83 likewise functions not only as a support for the other end of the cathode but also as a heating current conductor. But both these wires cannot be electrically connected to mounting plate 81 because the cathode would then be short-circuited. Hence it is necessary to insulate wire 83 from the mounting plate while supporting it thereon. This is accomplished by running wire 83 through an insulator secured in place on mounting plate 81 by a clamp 84. Wire 83 connects with a flexible corrugated metallic ribbon 85 and then extends back to the aforementioned insulator where its end is clamped in place by clamp 84. The corrugated metal ribbon 85 is supported, in turn, by a U-shaped rigid wire 86 which is held by an insulator at 87 (see Figs. 4 and 6). Cathode heating current is supplied through a circuit including a wire conductor 88 extending through metal tube 65 and insulated by a glass tube 89. Conductor 88 passes along into glass tube 67 and out through the side thereof by way of an appropriate seal at 90 (see Fig. 1). It proceeds thence to the center contact of plug 61. The other leg of the cathode heating circuit includes the several metallic parts of the focusing mechanism and conductor 91 shown in Fig. 1.

From the description so far given it will be manifest that in response to manipulations by the operator of lever 49, cathode 39 is moved laterally in one direction or the other, depending upon the direction of movement of lever 49; and it will be evident that the reason for so moving the cathode is to place the focal spot on different parts of the target as illustrated in the series of views of Fig. 14.

What principally remains to be described is the mechanical arrangement for effecting the movements of the focusing elements 31, 32, 33 and 34— which movements are clearly illustrated in Figs.

15 and 16. This mechanical arrangement consists of two groups of parts, namely: those which effect the movements of the lateral focusing elements 31 and 32 and those which effect the movements of the longitudinal focusing elements 33 and 34. These two groups, however, are mechanically connected and they operate in unison so that the movements of one are definitely related to those of the other, thereby maintaining a substantially constant proportionality between the length and breadth of the actual focal spot.

The parts of the first group comprise a link 92 which is pivotally connected at 73 to stanchion 39 and pivoted at its opposite extremity to a pair of arms 93 and 94 through the medium of a pin 95. Arms 93 and 94 are welded to the U-shaped strap 40 and thus rigidly connected to lateral focusing element 32. Strap 40 is pivotally connected to the mounting plate 81 and 96. These parts, together with the bifurcated link 36, constitute the principal components of the group having to do solely with the movements of the lateral focusing elements. Other parts of the adjusting mechanism obviously enter into the actuation of this group but do not pertain solely to it.

Operation of the lateral focusing group comprising parts 31, 32, 36, 40, 92, 93, 94, 95 and 96 etc. is as follows: The movements of arm 71 are transmitted to the flexible metal strip 75 through link 77. This causes a lateral movement of the cathode and mounting plate 81, which movement is transmitted to strap 40 through pivots 96. As a consequence, a rather involved link motion occurs (which is more readily illustrated than described) and results in a simultaneous rotation as a whole and a separation and drawing together of the lateral focusing elements 31 and 32. The motion of the latter elements is well illustrated in Fig. 15 and the operation of the link mechanism which brings about this result can be readily understood from a comparative examination of Figs. 4 and 5—the first of which shows the mechanism adjusted for fine focus and the latter for broad focus. Compare A and D of Fig. 15.

The group of parts for effecting the focus adjusting movements of focusing elements 33 and 34 comprises a pair of crossed links 97 and 98 respectively (see Fig. 9), the former being pivoted at 99 to the mounting plate 81 and the latter pivoted at 100, likewise to the mounting plate. Focusing element 33 is rigidly welded at 101 to the free end of link 98 while focusing element 34 is rigidly welded at 102 to the free end of link 97.

Link 97 is slotted at 103—which slot is engaged by a pin 104, one end of which is rigidly connected to link 98. The other end of pin 104 is connected to one end of a link 105, the other end of which is pivotally connected to a pair of arms 106 and 107 through the medium of a pin 108. Arms 106 and 107 are rigidly welded to strap 40. It will be seen that the movements of arms 106 and 107 are transmitted through pin 108 and link 105 to pin 104 and thence to links 97 and 98 which are thus caused to rotate in a small arc about their respective pivots 99 and 100. These links carry with them focusing elements 33 and 34 and bring about the movements thereof illustrated in Fig. 16.

The curved plate 109 disposed to the rear of the cathode and attached to mounting plate 81 serves to reduce dissipation of heat from the cathode.

In Figs. 18, 19 and 20 is illustrated an X-ray tube in three positions wherein the actual focal

spot is adjustably variable laterally but of fixed length. The target here is identified in each instance by reference numeral 110 and the cathode head by numeral 111. The table upon which the subject rests is identified by reference numeral 112. The dot and dash lines represent the limits of the projected length of the focal spot as seen by the subject—hence, what is termed the “apparent length”. By changing the angularity of the tube as depicted, it is evident that the apparent length of the focal spot can be varied while the actual length remains constant. Thus, by varying the width of the focal spot in the manner hereinbefore described and suitably tilting the tube an approximately equidimensional apparent focal spot can be obtained of any size between maximum and minimum.

Point 113 in Figs. 18, 19 and 20 is what is herein referred to as the viewpoint of the subject. It is that part of the patient or thing which is to be radiographed.

With the focus adjusting mechanism illustrated and described the size of the focal spot is variable continuously from fine to broad, that is, minimum to maximum and, obviously, any number of sizes of spot can be obtained between the two extreme limits. The operator, however, wants to be able to set his adjustment for a definite size focal spot the characteristics of which are known to him. For that reason a calibrated scale is provided as in Fig. 10. Only four scale divisions are shown because it is believed that four sizes of focal spot are sufficient for all purposes; but, manifestly, the scale can be calibrated as finely as may be desired.

For the diaphragm 63, I prefer to use chrome steel while for the other parts of the cathode head, iron, nickel or molybdenum may be employed.

In the manufacture of the tube described it is most convenient to assemble the cathode head on re-entrant stem 62 while the latter is detached from the main body of the envelope 21. The seal between the stem and the main body of the envelope is generally made at point 114—see Fig. 1.

What is claimed is:

1. An X-ray tube comprising, in combination, an evacuated envelope, a target, an electron-emissive linear cathode, focusing means in operative relation to said cathode, a mechanism for effecting relative movement between said cathode and said focusing means for adjustably varying the area of the focal spot, and an indicator operatively connected with said mechanism and operable to inform the operator as to the focal-spot adjustment, said target, cathode and focusing means being disposed within said envelope.

2. The combination in an X-ray tube of an evacuated envelope, a target, an electron-emissive cathode in operative relation to said target for the production of X-rays, non-automatic adjustable focusing means for concentrating the electron stream from said cathode into a beam of linear cross-section and directing said beam onto said target, said focusing means being operable, under control of the operator, for adjustably varying the cross-sectional width of said beam whereby to correspondingly vary the area of the focal spot produced thereby, and indicating means operatively connected with said focusing means and operable to inform the operator as to the focal-spot adjustment, said target, cathode and focusing means being disposed within said envelope.

3. The combination in an X-ray tube of an evacuated envelope, a target, an electron-emissive

cathode in operative relation to said target for the production of X-rays, adjustable focusing means for concentrating the electron stream from said cathode into a beam of linear cross-section and directing said beam onto said target, said focusing means being operable, under control of the operator, for adjustably varying the cross-sectional width and cross-sectional length of said beam whereby to correspondingly vary the area of the focal-spot produced thereby and indicating means operatively connected with said focusing means and operable to inform the operator as to the focal-spot adjustment, said target, cathode and focusing means being disposed within said envelope.

4. The combination in an X-ray tube of an evacuated envelope, a target, an electron-emissive linear cathode in operative relation to said target for the production of X-rays, lateral focusing means and longitudinal focusing means operable conjointly for concentrating the electron stream from said cathode into a beam of linear cross-section and directing said beam onto said target, and means under control of the operator for adjustably moving both said focusing means for varying proportionately the cross-sectional width and length of said beam whereby to correspondingly vary the dimensions of the focal spot produced thereby, said target, cathode and focusing means being disposed within said envelope.

5. The combination in an X-ray tube of an evacuated envelope, a target, an electron-emissive cathode in operative relation to said target for the production of X-rays, a pair of lateral focusing elements disposed respectively on either side of said cathode, said focusing elements being movable toward and away from said cathode and operable to concentrate the electron stream from said cathode into a beam of linear cross-section and to direct said beam onto said target, and a mechanism controllable by the operator for moving said focusing elements to vary the cross-sectional width of said beam and thus to vary the size of the focal spot, said target, cathode and focusing elements being disposed within said envelope.

6. The combination in an X-ray tube of an evacuated envelope, a target, an electron-emissive linear cathode in operative relation to said target for the production of X-rays, a pair of lateral focusing elements disposed respectively on either side of said cathode and a pair of longitudinal focusing elements disposed respectively at either end of said cathode, said lateral and longitudinal focusing elements being movable toward and away from said cathode and operable conjointly to concentrate the electron stream from said cathode into a beam of linear cross-section and to direct said beam onto said target, and a mechanism controllable by the operator for moving said focusing elements to vary the cross-sectional area of said beam and thus to vary the size of the focal spot, said target, cathode and focusing elements being disposed within said envelope.

7. The combination in an X-ray tube of an evacuated envelope having an aperture leading from the exterior to the evacuated interior thereof, a flexible metallic vacuum-tight closure for said aperture, a target, an electron-emissive linear cathode in operative relation to said target for the production of X-rays, adjustably variable focusing means for concentrating the electron stream from said cathode into a beam of linear cross-section, and mechanical focus-controlling

means extending through said flexible closure and connecting with said focusing means, said focus-controlling means being operable by and at the will of the operator for adjustably varying the size of the focal spot produced, said target, cathode and focusing means being disposed within said envelope.

8. The combination in an X-ray tube of an evacuated envelope having an aperture leading from the exterior to the evacuated interior thereof, a flexible metallic vacuum-tight closure for said aperture, a target, an electron-emissive cathode in operative relation to said target for the production of X-rays, adjustably variable focusing means for concentrating the stream of electrons from said cathode into a beam impinging upon said target, and a mechanism operable upon said focusing means for adjustably varying the size of the focal spot, said mechanism being also operable to direct said beam to each of a plurality of target areas successively whereby to vary the position of the focal spot thereon, said mechanism including said closure, said target, cathode and focusing means being disposed within said envelope.

9. A cathode head for an X-ray tube comprising, in combination, a linear cathode, a pair of lateral focusing elements for said cathode disposed respectively at either side thereof, a movable support for said cathode and focusing elements, a flexible metallic vacuum-tight closure element, a lever arm carried by said closure element, an interconnection between said lever arm and movable support, and means controllable by the operator for actuating said lever arm about said closure element as a fulcrum.

10. In an X-ray tube, a cathode head comprising, in combination, a cathode, an adjustably variable focusing device operatively associated with said cathode, a mechanism including links for operating said focusing device, a flexible closure element, said mechanism being connected with said closure element, and an operating lever connected to and carried by said closure element, said operating lever being accessible for manipulation from the exterior of the tube.

11. In an X-ray tube, a cathode head comprising, in combination, a linear cathode, a pair of complementary lateral focusing elements, a movable support for said cathode and focusing elements, a mechanism operable in response to actuation of said support for moving said focusing elements to adjustably vary the size of the focal spot, a flexible closure element, said movable support being connected with said closure element, and means for transmitting motion to said support through said closure element.

12. The combination in an X-ray tube of an evacuated envelope having an aperture leading from the exterior to the evacuated interior thereof, a target, an electron-emissive cathode in operative relation to said target for the production of X-rays, adjustably variable focusing means for concentrating the stream of electrons from said cathode into a beam impinging upon said target, and a mechanism operable upon said focusing means for adjustably varying the size of the focal spot, said mechanism including a flexible metallic vacuum-tight closure for said aperture, said mechanism also including a lever arm carried by said closure and extending into the evacuated space within said envelope, and a second lever arm carried by said closure and extending outwardly therefrom, said closure functioning as a fulcrum for said lever arms, said target, cathode

and focusing means being disposed within said envelope.

13. An X-ray tube comprising, in combination, an evacuated envelope, a target within said envelope, a linear cathode within said envelope in operative relation to said target for the production of X-rays, adjustably variable focusing elements for concentrating the electron stream from said cathode into a linear beam impinging upon said target, and means controllable by the operator for directing said beam to each of a plurality of target areas successively whereby to vary the position of the focal spot thereon at the will of the operator, said means being also operable upon said focusing elements to vary the size of the focal spot produced by said beam, said means including a support for said cathode which is movable together with said cathode laterally of the direction of propagation of said beam and laterally of said cathode.

14. An X-ray tube comprising, in combination, an evacuated envelope, a target within said envelope, an electron-emissive linear cathode within said envelope in operative relation to said target for the production of X-rays, focusing means in operative relation to said cathode, and a manually operable mechanism for effecting relative movement between said cathode and said focusing means for adjustably varying the width of the focal spot, said focusing means comprising a pair of complementary focusing elements which are relatively movable with respect to each other in response to actuation of said mechanism.

15. An X-ray tube comprising, in combination, an evacuated envelope, a target within said envelope, an electron-emissive cathode within said envelope in operative relation to said target for the production of X-rays, adjustably variable focusing means within said envelope in operative relation to said cathode for variably concentrating the electron stream from said cathode into a beam and directing said beam onto said target, a manually operable adjusting mechanism connected with said focusing means for effecting changes in the size of the focal spot produced by said beam, and means external of said envelope and connected with said mechanism for indicating to the operator the size of the focal spot which the focusing means is adjusted to produce.

16. The combination in an X-ray tube of an evacuated envelope, a target and an electron-emissive cathode within said envelope, said cathode being in operative relation to said target for the production of X-rays, focusing means including a lateral movable focusing element, said element being disposed on one side of said cathode and movable toward and away from said cathode, said focusing means being operable to concentrate the electron stream from said cathode into a beam of linear cross-section and to direct said beam onto said target, and a mechanism controllable by the operator for moving said focusing element to vary the cross-sectional area of said beam and thus to vary the size of the focal spot, said target, cathode and focusing means being disposed within said envelope.

17. An X-ray tube comprising, in combination, an evacuated envelope including a re-entrant stem having an aperture leading into the evacuated interior thereof, a target, a cathode head in operative relation to said target for the production of X-rays, said cathode head including an electron-emissive cathode, a flexible metallic diaphragm sealed to said stem and forming a vacuum-tight closure for said aperture, an ad-

justably variable focusing device and a mechanism operable through said diaphragm for actuating said focusing device to vary the size of the focal-spot, said cathode head being supported by said stem, said target and cathode head being disposed within said envelope.

18. An X-ray tube comprising, in combination, an evacuated envelope including a re-entrant stem having an aperture leading into the evacuated interior thereof, a target, a cathode head in operative relation to said target for the production of X-rays, said cathode head including an electron-emissive cathode, a flexible metallic diaphragm sealed to said stem and forming a vacuum-tight closure for said aperture, an adjustably variable focusing device and a mechanism operable through said diaphragm for actuating said focusing device to vary the size of the focal-spot, said mechanism including a lever arm carried by said diaphragm, said diaphragm operating as a fulcrum for said lever arm, said lever arm being, in part at least, of glass tubing, said cathode head being supported by said stem, said target and cathode head being disposed within said envelope.

19. The combination in an X-ray tube of an evacuated envelope having an aperture leading from the exterior to the evacuated interior thereof, a flexible vacuum-tight closure for said aperture, a target, an electron-emissive cathode in operative relation to said target for the production of X-rays, adjustably variable focusing means for concentrating the electron stream from said cathode into a beam of linear cross-section, and mechanical focus-controlling means extending through said closure and connecting with said focusing means, said focus-controlling means being operable by and at the will of the operator for adjustably varying the size of the focal spot produced, said target, cathode and focusing means being disposed within said envelope.

20. The combination in an X-ray tube of an evacuated envelope having an aperture leading from the exterior to the evacuated interior thereof, a flexible vacuum-tight closure for said aperture, a target, an electron-emissive cathode in operative relation to said target for the production of X-rays, means for concentrating the electron stream from said cathode into a beam of linear cross-section and directing the same onto said target, said means comprising a plurality of focusing elements which are moveable with respect to said cathode and with respect to each other, said focusing elements being directly operable upon the electron stream to determine its cross-sectional area and consequently the area of the focal spot produced upon said target, and a focus-adjusting mechanism connected with and operable to move said focusing elements and thereby to vary the area of the focal spot, said mechanism being also connected with said closure and including a part outside said envelope for manipulation by the operator, whereby the operator is enabled to vary the area of the focal spot at will, said target, cathode and focusing elements being disposed within said envelope.

21. The combination in an X-ray tube of an evacuated envelope, a target, an electron-emissive cathode in operative relation to said target for the production of X-rays, a plurality of adjustably movable focusing elements situated adjacent said cathode and operable conjointly to concentrate the electronic emission therefrom into a beam of linear cross-section, and a focus-adjusting mechanism extending through the

wall of said envelope from the exterior to the evacuated interior thereof, said mechanism being connected with and operable upon said focusing elements to vary the cross-sectional area of said beam, said target, cathode and focusing elements being disposed within said envelope.

22. The combination in an X-ray tube of an evacuated envelope, a target and an electron-emissive cathode in operative relation to said target for the production of X-rays, means situated adjacent said cathode for concentrating the electronic emission therefrom into a beam of linear cross-section and directing said beam onto said target, said means including an adjustably movable focusing-element for varying the cross-sectional length of said beam, and a second adjustably movable focusing-element for varying the cross-sectional width of said beam, and a focus-adjusting mechanism extending through the wall of said envelope from the exterior to the evacuated interior thereof, said mechanism being connected with and operable upon said movable focusing elements and arranged for manipulation by the operator for varying the area of the focal spot, said target, cathode and focusing elements being disposed within said envelope.

23. The combination in an X-ray tube of an evacuated envelope, a target, an electron-emissive cathode in operative relation to said target for the production of X-rays, and means situated adjacent said cathode for concentrating the electronic emission from said cathode into a beam and directing the same onto said target, said means comprising a plurality of focusing elements, at least one of which is adjustably movable relatively to another, and means for holding at least one of the movable focusing elements in any position of adjustment to which it may be adjusted, said target cathode and focusing elements being disposed within said envelope.

24. The combination in an X-ray tube of an evacuated envelope, a target, an electron-emissive cathode in operative relation to said target for the production of X-rays, and means situated adjacent said cathode for concentrating the electronic emission from said cathode into a beam and directing the same onto said target, said means comprising a plurality of focusing elements, at least one of which is adjustably movable relatively to another and to said cathode, and means for holding at least one of the movable focusing elements in any position of adjustment to which it may be adjusted, said target, cathode and focusing elements being disposed within said envelope.

25. The combination in an X-ray tube of an evacuated envelope, a target, an electron-emissive cathode in operative relation to said target for the production of X-rays, and means situated adjacent said cathode for concentrating the electronic emission from said cathode into a beam and directing the same onto said target, said means comprising a plurality of focusing elements, at least one of which is adjustably movable relatively to said cathode, and means for holding at least one of the movable focusing elements in any position of adjustment to which it may be adjusted, said target, cathode, and focusing elements being disposed within said envelope.

26. The combination in an X-ray tube of an evacuated envelope, a target, an electron-emissive linear cathode in operative relation to said

target for the production of X-rays, and means situated adjacent said cathode for concentrating the electronic emission therefrom into a beam and directing the same onto said target, said means comprising a plurality of focusing elements each of which is adjustably movable relatively to another and to said cathode, and means for holding each of said focusing elements in any position of adjustment to which it may be adjusted, said target, cathode and focusing elements being disposed within said envelope.

27. The combination in an X-ray tube of an evacuated envelope having a re-entrant stem, a target, an electron-emissive cathode in operative relation to said target for the production of X-rays, focusing means situated adjacent said cathode for concentrating the electron emission therefrom into a beam of linear cross-section and directing said beam onto said target, said focusing means comprising a plurality of relatively movable focusing elements, a focus-adjusting mechanism connected with said focusing elements and including a rod extending from the exterior to the evacuated interior of said envelope, a flexible vacuum-tight joint interconnecting said rod and envelope and functioning as a yieldable support for said rod, said cathode and focusing elements being mounted upon said re-entrant stem and disposed, together with said target, in the evacuated space within said envelope.

28. In an adjustable-focus X-ray tube, an evacuated envelope, a target, an electron-emissive cathode, focusing means situated adjacent said cathode, said cathode and focusing means being relatively movable for varying the area of the focal spot, a focus-adjusting mechanism partly within said envelope for effecting relative movement between said cathode and focusing means, said focus-adjusting mechanism including an operating lever extending outside the evacuated interior of said envelope, said operating lever being arranged for manipulation by the operator for effecting focal spot adjustments, and means for holding said focus-adjusting mechanism in any operating position to which it happens to be adjusted.

29. In an adjustable-focus X-ray tube, an evacuated envelope, a target, an electron-emissive cathode in operative relation to said target for the production of X-rays, focusing means situated adjacent said cathode, said cathode and focusing means being relatively movable for varying the area of the focal spot, a focus-adjusting mechanism for effecting relative movement between said cathode and focusing means, means for holding said focus-adjusting mechanism in any operating position to which it happens to be adjusted, a calibrated scale mounted on said tube and a pointer registering with said scale and arranged to move thereover in response to actuation of said focus-adjusting mechanism for indicating to the operator the focal spot adjustment, said target, cathode and focusing means being disposed within said envelope.

30. The combination in an X-ray tube of an evacuated envelope, a target within said envelope, an electron-emissive linear cathode within said envelope in operative relation to said target for the production of X-rays, focusing means within said envelope situated adjacent said cathode for concentrating the electronic emission therefrom into a beam of linear cross-section and directing said beam onto said target, said focusing means comprising two pairs of comple-

mentary relatively movable focusing elements, the members of one of said pairs of focusing elements being disposed at either side of said cathode and operable to control and vary the cross-sectional width of the electronic beam, the members of the other of said pairs of focusing elements being disposed at either end of said cathode and operable to control and vary the cross-sectional length of the electronic beam, and means for holding each of said focusing elements in any position of adjustment to which it may be set.

31. The combination in an X-ray tube of an evacuated envelope including a re-entrant stem having an aperture, a target within said envelope, an electron-emissive linear cathode within said envelope in operative relation to said target for the production of X-rays, focusing means situated adjacent said cathode for concentrating the electronic emission therefrom into a beam of linear cross-section and directing said beam onto said target, said focusing means comprising two pairs of complementary relatively movable focusing elements, the members of one of said pairs of focusing elements being disposed at either side of said cathode and operable to control and vary the cross-sectional width of the electronic beam, the members of the other of said pairs of focusing elements being disposed at either end of said cathode and operable to control and vary the cross-sectional length of the electronic beam, said cathode and focusing elements being mounted upon said re-entrant stem, a flexible diaphragm sealed to said re-entrant stem and forming a vacuum-tight closure for the aperture therethrough, a focus-adjusting mechanism including a tubular lever extending through and connected to said diaphragm, said diaphragm functioning as a fulcrum for said lever, one arm of said lever extending into the evacuated space within said envelope and connected through other parts of said focus-adjusting mechanism with said focusing elements, the other arm of said lever extending outwardly from said evacuated space, a glass tube attached and sealed to the end of said last mentioned arm, a fulcrumed arm engaging the free end of said glass tube, a manually operable lever drivingly connected with said arm, frictional retarding means engaging said last mentioned lever and operable to hold the same in any operating position to which it happens to be adjusted, a pointer carried by said last mentioned lever, and a calibrated scale mounted upon said tube and registering with said pointer for indicating the focal spot adjustment.

32. The combination in an X-ray tube of an evacuated envelope, a target, an electron-emissive linear cathode in operative relation to said target for the production of X-rays, a plurality of focusing elements situated adjacent said cathode for concentrating the electronic emission therefrom into a beam of linear cross-section and directing the same onto said target, at least one of said focusing elements being adjustably movable relatively to said cathode for varying the cross-sectional area of said beam, and a focus-adjusting mechanism operable upon said adjustably movable focusing element for effecting variations in the area of the focal spot, said focus-adjusting mechanism including a vacuum-tight closure element secured to the wall of said envelope and operable as a medium for the transmission of mechanical motion from the exterior of said envelope to the interior

thereof without impairing the vacuum therein, said target, cathode and focusing elements being disposed within said envelope.

33. The combination in an X-ray tube of an evacuated envelope containing a target and an electron-emissive cathode spaced from and in operative relation to said target for the production of X-rays, means within said envelope defining a passageway for electrons proceeding from said cathode to said target, said passageway being interposed between said cathode and said target and serving to determine the area of the focal spot produced upon said target, said passageway being adjustably variable as to size for varying the area of the focal spot, and non-vacuum-impairing focal-spot-adjusting means for varying the size of said passageway and thus varying the area of the focal spot.

34. The combination in an X-ray tube of an evacuated envelope containing a target and an electron-emissive cathode spaced from and in operative relation to said target for the production of X-rays, means within said envelope defining an adjustably variable passageway for electrons proceeding from said cathode to said target, said passageway being interposed between said cathode and said target and serving to determine the area of the focal spot produced upon said target, said passageway being adjustably variable in two dimensions for varying the length and breadth respectively of the focal spot, and non-vacuum-impairing focal-spot-adjusting means for varying the size of said passageway and thus varying the area of the focal spot.

35. The combination in an X-ray tube of an evacuated envelope containing a target and an electron-emissive cathode spaced from and in

operative relation to said target for the production of X-rays, means within said envelope defining a passageway for electrons proceeding from said cathode to said target, said passageway being interposed between said cathode and said target and having approximately parallel opposing sides which function to concentrate the electronic emission from said cathode into a beam of linear cross-section, said passageway being adjustably variable as to size for varying the area of the focal spot, and non-vacuum-impairing focal-spot-adjusting means for varying the size of said passageway and thus varying the area of the focal spot.

36. The combination in an X-ray tube of an evacuated envelope containing a target and an electron-emissive cathode spaced from and in operative relation to said target for the production of X-rays, means within said envelope defining a passageway for electrons proceeding from said cathode to said target, said passageway being interposed between said cathode and said target and serving to determine the area of the focal spot produced upon said target, said passageway being adjustably variable as to size for varying the area of the focal spot, and focal-spot-adjusting means extending from the exterior of said envelope to the evacuated interior thereof for varying the size of said passageway and thus varying the area of the focal spot, said focal-spot-adjusting means including an element operable to permit the transmission of mechanical motion from the exterior of said envelope to the evacuated interior thereof without impairment of the vacuum therein.

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