July 12, 1938. J. F. LEE 2,123,607

VARIABLE FOCUS X-RAY TUBE

Filed Aug. 19, 1931 2 Sheets-Sheet 1

Fig. 1.

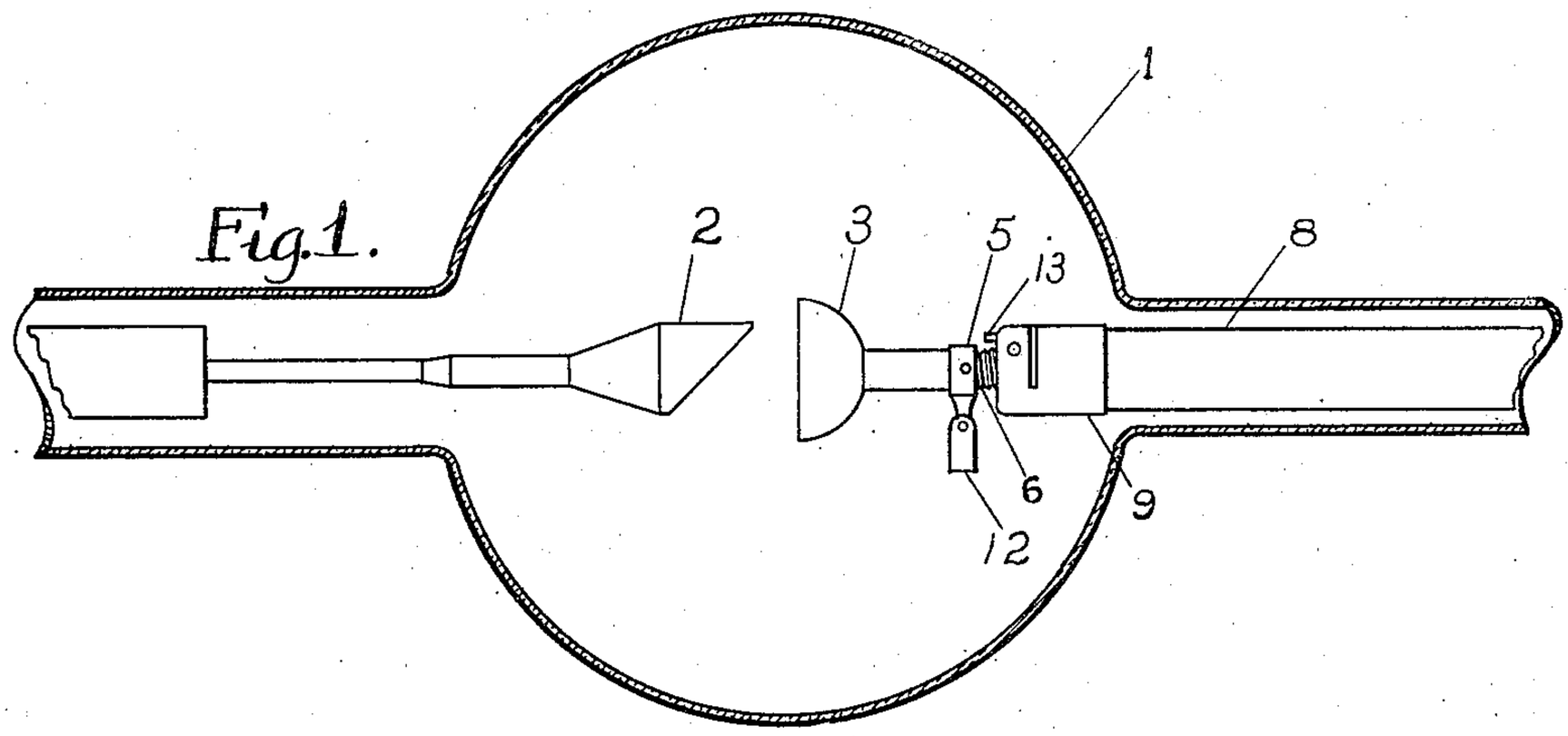

Fig. 2.

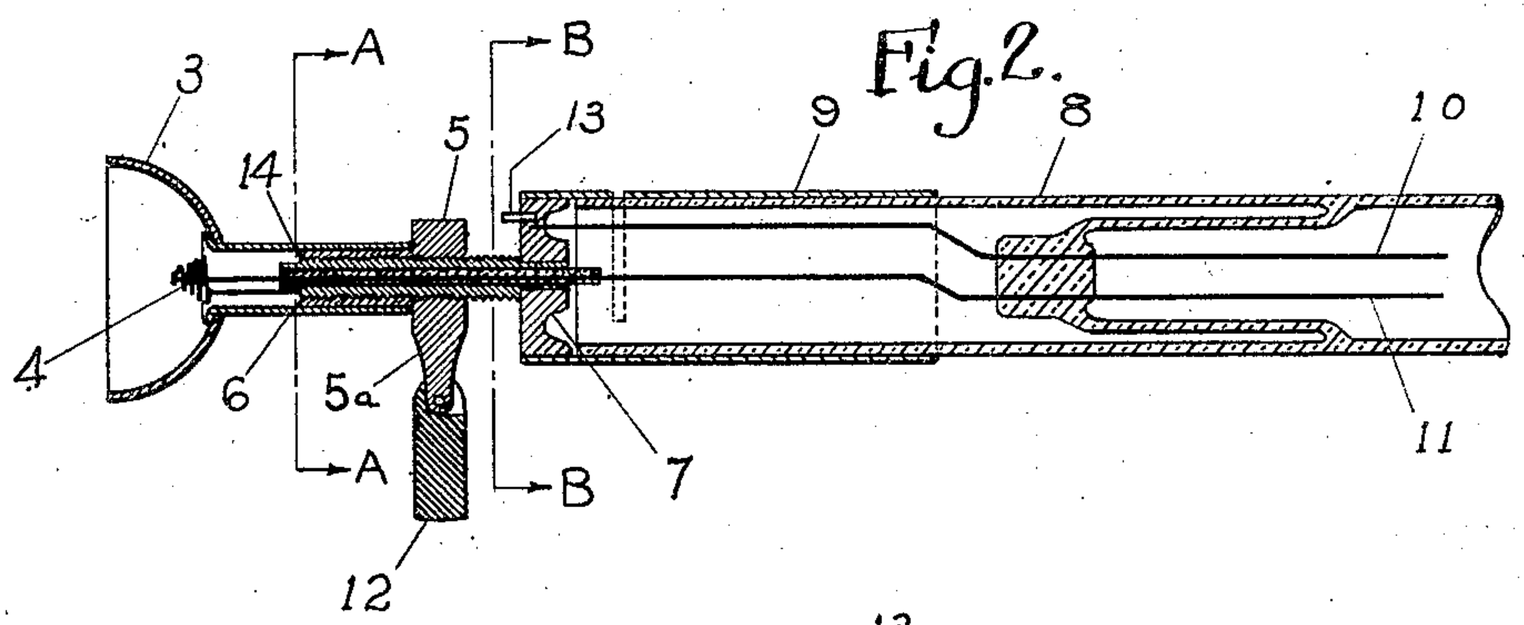

Fig. 3

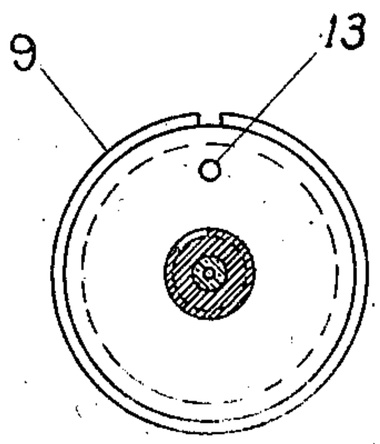

Fig 4

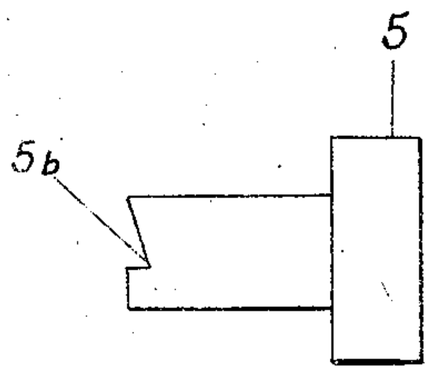

Fig. 5

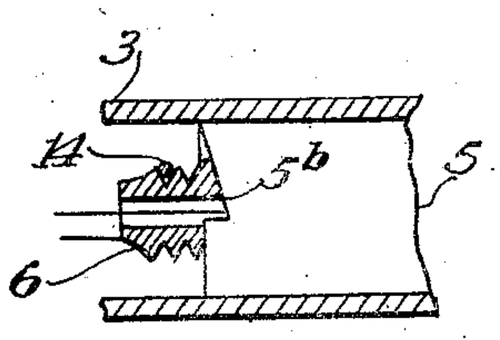

Fig. 3a

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VARIABLE FOCUS X-RAY TUBE

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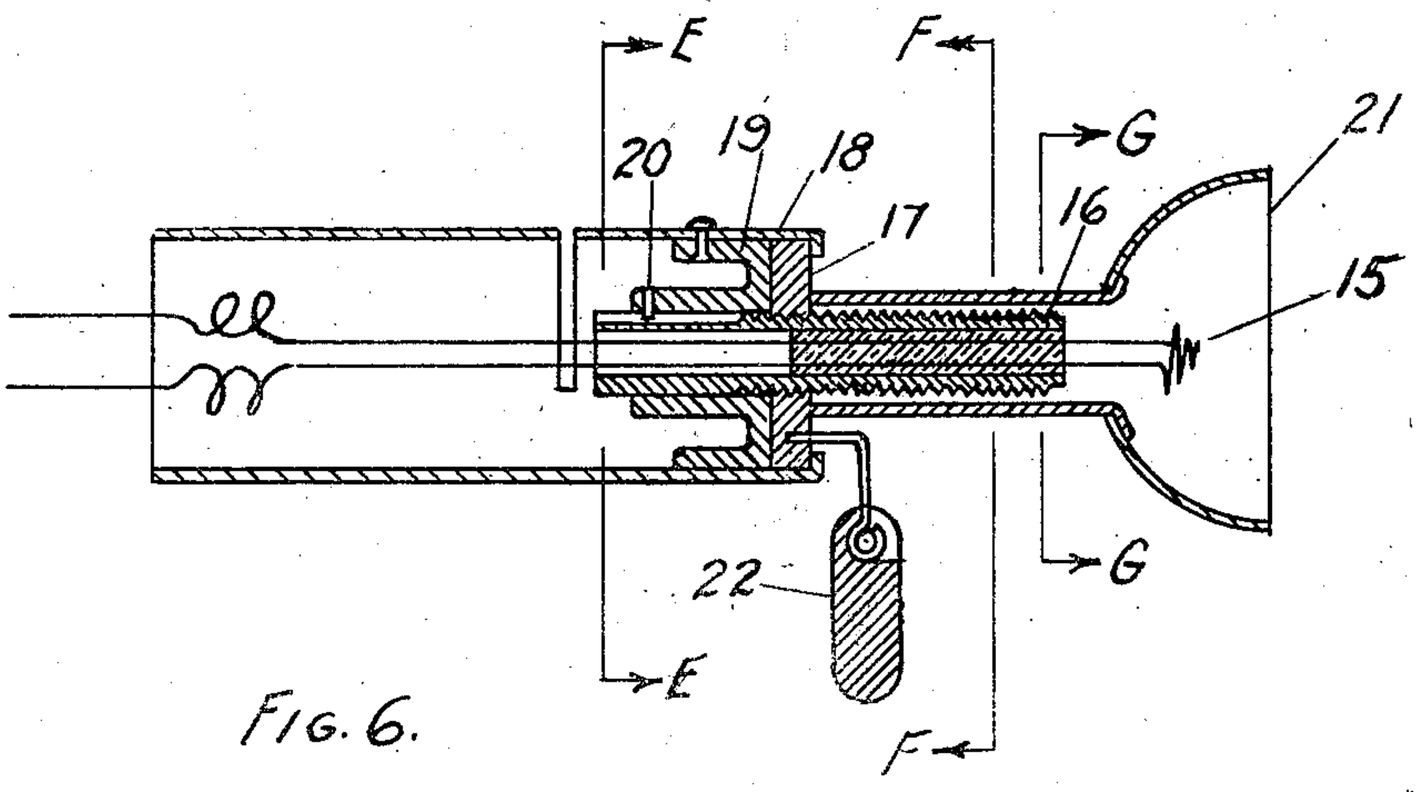

FIG. 6.

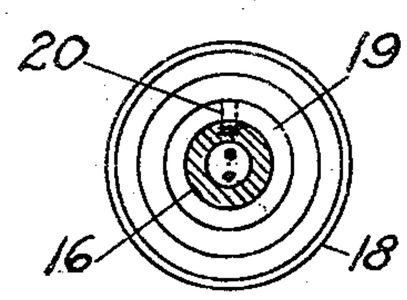

FIG. 7.

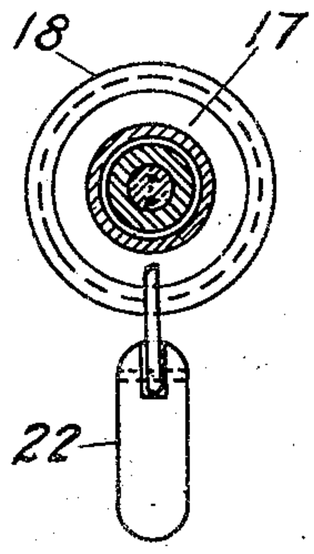

FIG. 8.

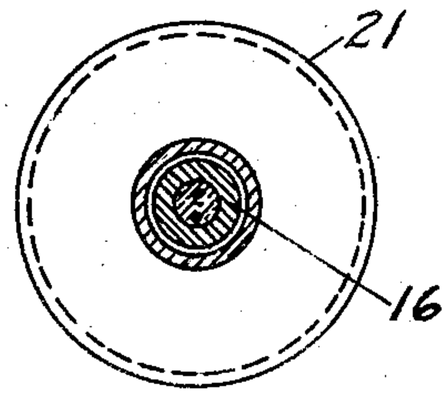

FIG. 9.

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VARIABLE FOCUS X-RAY TUBE

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Application August 19, 1931, Serial No. 557,982

3 Claims. (Cl. 250—35)

This invention relates to X-ray tubes of the hot cathode type, the primary object being to provide a commercially practicable tube of this character wherein the area of the focal spot can be selectively adjusted by the operator conformably to his momentary needs.

To meet properly the requirements of the several uses to which X-ray tubes are put, especially in medical practice, it has heretofore been essential that the practitioner or technician have at his disposal an array of tubes comprising a variety of sizes of focal spot. These tubes are costly and the average physician of modest means who has only infrequent need for focal spots of certain sizes usually cannot afford to provide himself with a complete assortment. The present invention meets this exigency by providing an X-ray tube in which the area of the focal spot can be selectively and quickly adjusted by the operator, and which is not substantially more expensive to manufacture than a conventional fixed-focus tube. This is accomplished through the provision of a mechanism whereby the operator can vary at will the space relation between the hot cathode and the focusing cup or shield.

The fundamental concept of an X-ray tube wherein the size of the focal spot can be altered at the will of the operator by effecting a movement of the focusing shield relatively to the hot cathode is not new but, on the contrary, was long ago suggested and disclosed by Dr. Irving Langmuir in his U. S. Patent No. 1,251,388, granted December 25, 1917, wherein is shown a hot cathode X-ray tube having a focusing shield which is movable relatively to the hot cathode by means of an external electro-magnet—the focusing shield being made of iron.

Upon examination of the aforementioned patent it will be self-evident that Langmuir's showing is not that of a commercially feasible X-ray tube, but merely an arrangement devised and intended solely to illustrate the broad idea in the easiest possible way. The present invention, on the contrary, is the outcome of extensive inventive thought and commercial development, and entails features of vital importance not to be found in the prior art and which are indispensable from the standpoint of practical utility.

One of the features of the present invention, wherein it is distinguished from the prior art, including the disclosure of the Langmuir patent, is that the focusing shield and cathode are both mounted upon and supported by a re-entrant stem. In the Langmuir structure, the focusing shield is not carried by the re-entrant stem but directly by the cathode arm—which greatly reduces the effective insulation between the high voltage terminals, besides being exceedingly crude and unsatisfactory from both the operating and manufacturing standpoints.

A second feature of the present invention, wherein it is further distinguished from the prior art, including the disclosure of Langmuir, is that the mechanism for effecting adjustments of the space relation between the hot cathode and the focusing shield is located inside the evacuated envelope and is physically connected with either the focusing shield or the cathode so as to effect a positive relative movement between those elements in response to appropriate manipulation by the operator.

A third feature of the present invention, wherein it is also further distinguished from the prior art, including the disclosure of Langmuir, is that the adjusting mechanism is mounted upon the re-entrant stem together with the hot cathode and focusing shield. This not only avoids the impairment of insulation inherent in the arrangement of Langmuir, but makes for great convenience in manufacture as will later be evident.

Still another distinguishing characteristic of the present invention is that the focus-adjusting device is mechanically connected with the cathode or focusing shield, as the case may be. This is a point of distinction not dependent upon the fact that in the specific arrangements shown the adjusting devices are carried by the re-entrant stem.

With an X-ray tube constructed according to either of the embodiments of this invention as illustrated and described herein, the space relation between cathode and focusing shield can be varied in exact measured amounts with the certainty that a given manipulation of the adjusting mechanism will result in a focal spot of a definite predetermined area, with no possibility of injury to the target arising from failure of the focusing shield or cathode to move to the exact extent expected. This is because the focus-adjusting operation is effected mechanically and positively—a condition not obtaining in the structure of the Langmuir tube, as illustrated in the Langmuir patent referred to above.

Two more or less alternative embodiments of the invention are illustrated in the drawings which accompany this specification, wherein:

Fig. 1 is a fragmentary elevational view, partly in cross section, of an X-ray tube in which the focusing shield is adjustable;

Fig. 2 is a longitudinal section of a portion of the tube shown in Fig. 1. This view shows the cathode focusing shield and illustrates the manner in which the latter is rendered adjustable with respect to the cathode;

Fig. 3 is a cross-sectional view taken along the line A—A of Fig. 2;

Fig. 3*a* is a sectional view taken along the line C—C of Fig. 3;

Fig. 4 is a cross-sectional view taken along the line B—B of Fig. 2;

Fig. 5 is a detail of one of the parts shown in Fig. 2;

Fig. 6 is a longitudinal sectional view illustrating an arrangement wherein the cathode is adjustable with reference to a fixed focusing shield;

Figs. 7 to 9 inclusive, are cross-sectional views taken along the lines E—E, F—F and G—G respectively of Fig. 6.

Except as modified in accordance with the present invention, the X-ray tube shown fragmentarily in Fig. 1 may be regarded as a conventional Coolidge high vacuum tube; and since such tubes are very well known, it is unnecessary to explain its construction and operation in detail beyond what may be required in order adequately to describe the invention. It differs from the conventional X-ray tube in that the focusing shield is adjustable, that is, movable axially with reference to the cathode—the latter being stationary.

Referring to Figs. 1 to 5 inclusive, **1** is the glass envelope; **2** is a tungsten anode or target of the usual form; **3** is the focusing shield or cup, preferably molybdenum; **4** is the filamentary cathode which is preferably of the usual conical form, but not necessarily so; **5** is a metal nut of special form, being threaded internally to engage the externally threaded tubular metal supporting member **6**, the latter being rigidly attached to a metal flange **7** which is, in turn, attached to a re-entrant tubular glass stem **8** through the medium of an expansible sleeve **9**. The focusing shield **3** is attached to and movable with nut **5** as clearly shown in Fig. 2. A pair of leading-in conductors **10** and **11** connect with the filament as shown.

A weight **12** carried by nut **5** serves to restrain the latter, together with the focusing shield, against rotation when the tube is rotated upon its axis. Thus by rotating the X-ray tube as a whole the nut **5** together with focusing shield **3** is caused to travel axially one way or the other as determined by the direction of rotation. It will be understood that the nut is advanced axially by reason of its screw-thread engagement with supporting member **6** which rotates as the whole tube is rotated whereas the nut **5** does not rotate. Weight **12** is pivotally attached to nut **5** for convenience in assembling the tube. The pivotal attachment has nothing to do with the functioning of the weight as above described.

To prevent nut **5** binding when it reaches either end of its travel, as it would if special preventive measures were not taken to the contrary, there is provided a pin **13** which engages the arm **5***a*, forming an integral part of nut **5**—this engagement being effective to prevent further relative rotation before nut **5** can make contact with the face of flange **7**. It will be observed that if nut **5** were permitted to engage firmly the face of flange **7** the threads would likely bind, thereby making further adjustment, that is, reverse movement of the nut, difficult if not impossible. A similar provision is made at the other extremity of travel of nut **5**. In Fig. 5 the nut is shown to be notched as at **5***b*. This notch engages a piece of wire **14** or other suitable obstacle as shown most clearly in Figs. 3 and 3*a*.

The short piece of wire **14** lies in the groove of the thread and is firmly secured to member **6** by brazing or welding. In operation, that face of the notch **5***b* which is parallel to the axis of the nut **5** collides with one end of wire **14**, the impact being in a direction parallel to the thread groove. Thus, the rotation of nut **5** is stopped abruptly with little or no force being developed in the direction of the axis of nut **5** and member **6**. Hence there is little or no tendency for the threads to bind—which, if it did occur, would cause nut **5** to stick. The binding action which it is sought to avoid is the same as that which occurs in the case of the use of a check nut on a set-screw.

It is scarcely necessary to explain that the area of the focal spot on the target may be regulated by adjusting the position of the focusing shield with respect to the cathode and that this is accomplished by simply rotating the whole tube upon its own axis in the appropriate direction. With the shield in its furthermost position toward the target the area of the focal spot is a minimum and vice versa. It is thought that there is no occasion to explain why this is so, since the phenomenon is well known and made use of in the design of ordinary fixed focus tubes.

The focusing shield has been shown in each case as of the cup type, but other forms may be used as, for instance, the ordinary tubular shield.

Another form of the invention as applied to X-ray tubes is shown in Figs. 6 to 9 inclusive. Here the cathode is adjustable with respect to a fixed focusing shield and a fixed anode. The anode and envelope are not shown. They may be assumed to be of the conventional form and situated with reference to the cathode the same as in Fig. 1.

Referring more especially to Fig. 6, the filament **15** is carried by and movable axially of the tube with a tubular threaded member **16**. The latter is engaged by a rotatable internally threaded disc **17** which is held in place by a cup-like retainer **18** attached to the flange member **19**. Tubular member **16** is provided with a longitudinal slot which is engaged by a pin **20**. Thus member **16** is restrained against rotation. Focusing shield **21** is attached to disc **17**. A weight **22** attached to disc **17** serves to restrain the latter against rotation when the tube as a whole is rotated on its axis. The disc, it will be understood, rotates together with the focusing shield, relatively to the other parts of the tube; or, putting it the other way, the other parts of the tube rotate relatively to the disc and shield. It should be entirely clear from an examination of Fig. 6 that the filament **15** together with tubular member **16** moves axially with respect to the focusing cup when the X-ray tube as a whole is rotated on its axis.

Of course the direction of movement of the cathode is determined by the direction of rotation. Stops similar to those previously described should be provided, but it is not thought necessary to illustrate such obvious details in view of what has already been described in connection with previous figures of the drawings. It is believed that the sectional views of Figs. 7 to 9 inclusive need no comment.

The last described embodiment of the invention is manifestly very much an equivalent of that which was first described, but for certain practical reasons, which are more or less apparent, the first

described embodiment is distinctly the preferred one.

It will be observed that in the embodiments of the invention illustrated and described, the cathode, focusing shield and focus-adjusting mechanism are mounted together upon a re-entrant glass stem 8 and form an integral unit. It is obvious that by virtue of such arrangement the several parts mentioned can easily be assembled and adjusted outside the envelope and mounted upon the re-entrant stem as a unit. Not only does such an arrangement facilitate economical manufacture, but it results in no impairment of the insulation between the high voltage terminals of the tube—a factor of great importance. It will further be observed that in both of the arrangements illustrated the connection between the adjusting mechanism and the focusing shield or cathode, as the case may be, is positive and that a definite manipulation of the adjusting mechanism results in a definite predetermined relative movement between focusing shield and cathode. Hence, the operator is able selectively to adjust the tube to any one of a plurality of precise focal spot settings and to do so repeatedly. This is an important consideration because even small unintended variations in the focal spot area are apt to be injurious if not disastrous to the target.

In all the arrangements described the materials used may be those which are commonly employed in the manufacture of X-ray tubes.

In certain of the appended claims, the term "non-automatic" has been used for the purpose of more clearly distinguishing from the disclosure of Austrian patent No. 103,436. It will be noted that the Austrian patent referred to discloses an X-ray tube wherein the area of the focal spot is automatically adjusted in response to filament current variations, the purpose being to protect the target against the ordinary consequences of abnormal supply line voltages. Similarly, certain of the claims include the expression "non-vacuum-impairing means"; that expression being employed to differentiate from the disclosure of British patent No. 317,451 which is that of an X-ray tube in which the positions of the cathode and focusing shield can be altered by taking the tube apart.

What is claimed is:

1. In an X-ray tube, an evacuated envelope, a target, a hot cathode, and an electrically conductive focusing shield, all within said envelope, said focusing shield being operable to focus the cathode rays emitted by said cathode, and thereby to determine the area of the focal spot on said target, said cathode and focusing shield being relatively movable with respect to each other whereby the area of the focal spot is capable of adjustment, and a device within said envelope which is operable in response to rotation of said envelope to change the space relation between said cathode and said focusing shield a definite, predetermined amount per revolution of said envelope whereby the area of the focal spot is selectively and precisely adjustable without impairing the vacuum, said device including an element which is rotatable relatively to said envelope.

2. An X-ray tube comprising an evacuated envelope in which are enclosed a target, a hot cathode, and a focusing shield, said focusing shield being adjustably movable with respect to said cathode whereby to effect variations of the area of the focal spot, and an adjusting screw within said envelope, said adjusting screw being operatively connected with said focusing shield and manually operable to vary the position of said focusing shield with respect to said cathode.

3. An X-ray tube comprising an evacuated envelope in which are enclosed a target, a hot cathode and a focusing shield, a fixed support for said focusing shield, said focusing shield being mounted on said support in screw-thread association therewith, the arrangement being such that said focusing shield is progressively movable toward and away from said target in response to relative rotation between said focusing shield and its said support, and means operable to restrain said focusing shield against rotation when said envelope is rotated, whereby to effect variations of the area of the focal spot.

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