Nov. 5, 1957 T. W. MALTBY ET AL 2,812,462

ANODE STRUCTURE

Filed May 18, 1953

Fig. 1

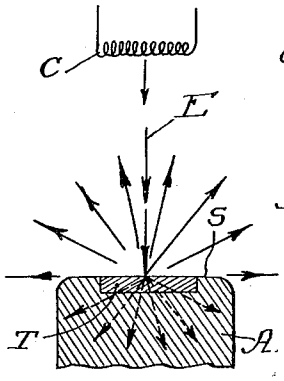


Fig. 2

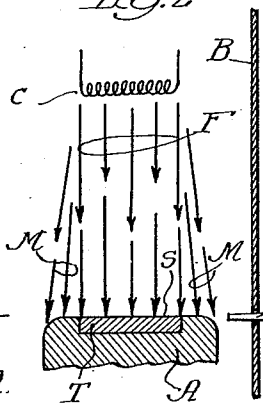


Fig. 3

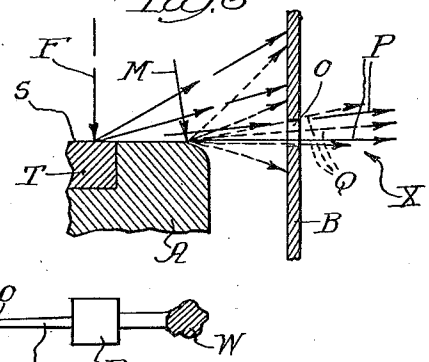


Fig. 4

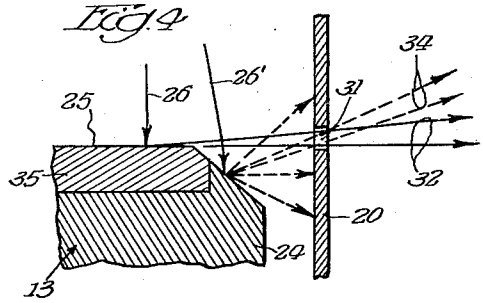


Fig. 5

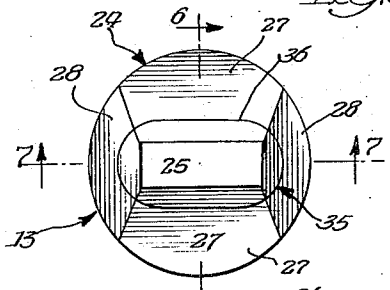


Fig. 6

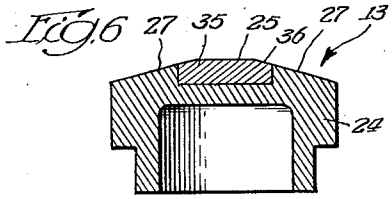


Fig. 7

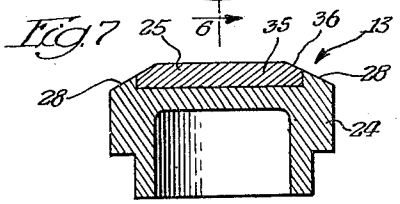


Fig. 8

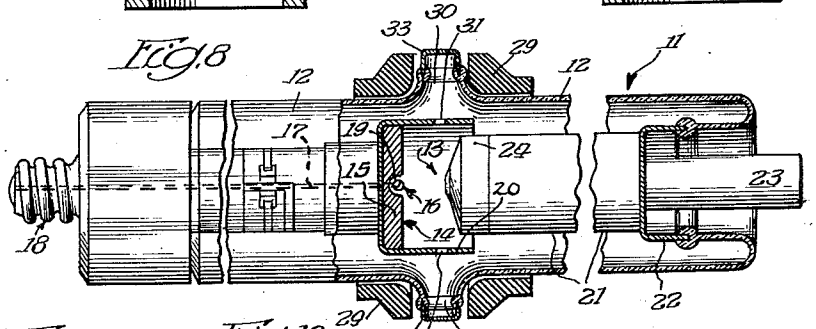


Fig. 9

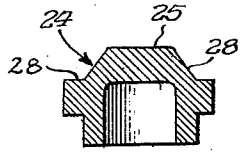


Fig. 10

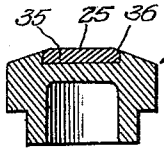
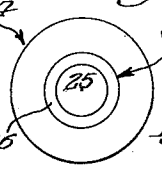


Fig. 11



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ANODE STRUCTURE

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3 Claims. (Cl. 313—55)

The present invention relates in general to electronics, and has more particular reference to electron flow devices, such as X-ray generating tubes, the invention relating, in its specific aspects, to an improved electrode construction especially well suited for anti-cathodic service in X-ray generating tubes.

X-rays may be generated by causing the impingement of electrons, emitted from a suitable cathode, upon an anti-cathode or anode, such cathode and anode being usually enclosed within a sealed, evacuated envelope and comprising an X-ray generating tube. Electron impingement upon a target surface of the anode, at relatively high velocity, constitutes the target surface as a source of X-rays, at the zone or area of electron impingement, the so generated X-rays being emitted thence through and outwardly of the enclosing envelope as a useful beam of X-rays.

For certain purposes, as in the application of X-rays to diffraction analysis, it is desirable not only to control the production of a sharply defined X-ray beam, but also to exclude from said beam all X-rays other than rays of predetermined character. In this connection, it should be understood that X-rays emitted from the anode of a generating tube provide a continuous spectrum, the characteristic wave length and distribution of which depends upon the material employed as an electron target, every target material having its own characteristic X-ray spectrum, which is independent of the operating potential applied between anode and cathode of the generating tube, above a minimum voltage, which minimum voltage is also characteristic of the particular target material involved.

Any suitable target material may, of course, be employed for X-ray diffraction analysis, providing that the target material and its characteristic X-ray spectrum are known, as otherwise spectral lines produced by the target material, in the spectrograph of the material under examination, may be mistaken for lines supposedly caused by the material being examined. The choice of a suitable target material for X-ray diffraction analysis depends, to a considerable extent, upon the nature of the material to be examined, the particular examination technique employed, and the type of information sought. It is obvious that, regardless of technique or the nature of the material under examination, a prerequisite for accurate analysis is the production of an X-ray beam containing only X-rays of selected spectral characteristics.

An important object of the present invention, therefore, is to control the emission of an X-ray beam from the anode of a generating tube in fashion producing a relatively sharply defined ray beam comprising only rays of desired spectral character, while excluding from the beam substantially all contaminant rays having different or undesired spectral characteristics.

A further object of the invention is to provide an improved anode structure, shaped and configurated in novel fashion and adapted, in conjunction with cooperating apertured or slitted shield means, to control emission from

the anode of a generating tube, of a narrow, sharply defined X-ray beam comprising only rays of desired spectral character.

Another important object is to provide an anode having an electron target surface including a central target portion of limited area, lying in position to receive electrons directed thereon from a cooperating cathode, and anode portions surrounding said central target portion and disposed rearwardly thereof, whereby X-rays generated through electron impact on said target portion may be emitted thence through apertured screen means as a sharply defined beam, while unwanted rays, generated by electron impact upon anode surfaces, outwardly of the central target portion, may be directed outwardly of and thus excluded from said well defined beam.

Another important object is to provide an anode having electron target surface portions of truncated conical or pyramidal configuration providing a central apexial surface portion lying in a plane transversely of the central axis of the pyramid, and surfaces extending outwardly of said apexial surface portion and rearwardly or downwardly thereof, said surfaces making angles with said apexial surface of at least 15°; a further object being to provide an anode having an apexial target surface portion of preferably elongated configuration, whereby the anode may be employed in combination with an elongated cathodic electron emission source disposed in spaced apart facing alinement with the longitudinal axis of the elongated apexial surface area of the anode.

Another important object is to provide, in conjunction with an anode of the character mentioned, a suitable slit structure for the transmission of a useful X-ray beam produced by electron impact on the target surface portion of the anode while excluding transmission, in the direction of said beam, of X-ray produced by electron impact on anode surfaces outwardly of said target surface portion; a further object being to provide an anode enclosing shield or screen of material relatively opaque to X-rays, and provided with window openings or slits substantially in alinement with the plane of the central target portions of the anode, whereby to block transmission, past said shield, of rays other than those generated as the result of electron impact on the central target portion of the anode.

The foregoing and numerous other important objects, advantages, and inherent functions of the invention will become apparent as the same is more fully understood from the following description, which, taken in connection with the accompanying drawings, discloses a preferred embodiment of the invention.

Referring to the drawings:

Figs. 1–4 are diagrams illustrating the manner of generating X-rays as the result of cathode ray electron impact upon an anodic electron target;

Fig. 5 is a face view of an anode embodying the present invention;

Figs. 6 and 7 are sectional views taken substantially along the lines 6—6 and 7—7 in Fig. 5;

Fig. 8 is a sectional view taken through an X-ray generator fitted with an anode embodying the present invention;

Figs. 9 and 10 are sectional views illustrating modified anodes embodying the invention; and

Fig. 11 is an end view of the anode shown in Fig. 10.

As shown more particularly in Fig. 1 of the drawings, X-rays may be generated at the target surface S of an anode A, as the result of impingement thereon of an electron E, emitted from a cathodic emission element C. Such generated rays are emitted uniformly in all directions radially of the point of impact of the electron E on the target. X-rays thus emitted, as shown in dotted lines in Fig. 1, in the hemispherical zone behind the plane of

the target surface, are usually substantially completely attenuated or absorbed by the material of the anode target. Rays emitted, as shown in solid lines in Fig. 1, within the hemispherical zone in front of the target surface, may be put to useful service.

When the cathodic emission element C is in operation, it will, of course, as shown more particularly in Fig. 2, emit continuously a stream or cloud of electrons in a direction causing electron impingement upon the anode substantially throughout the entire area of the surface S thereof which faces toward the emission element. The anode of an X-ray generating tube commonly provides a more or less sharply defined focal area within the anode surface S and upon which electrons emitted by the element C are caused to impinge, it being desirable to focus the electron beam as sharply as possible to cause electron impingement only within the limited focal area, in order that generated X-rays may emanate principally from said focal area and not to any substantial extent as the result of electron impact upon the anode surfaces outwardly of the focal area. The focal area may be and is commonly defined by the exposed surface of a target button T of desired target material, which may be embedded in the body of the anode in position exposed at the surface S thereof which faces toward the emission element C.

The target end of the anode, however, may comprise homogeneous material, in which case the focal area merely comprises a zone or spot within the target surface S of the anode which faces the electron emission element. Electron flow control means may be and commonly is provided for causing impingement of the electron beam within the focal area of the anode. As a consequence, the major portion of the electron beam normally comprises a stream of focused electrons F, all of which may impinge upon the anode within the focal area thereof, and stray or marginal electrons M which impinge upon the anode outwardly of the focal area.

Each electron, when it impinges upon the anode target surface S, whether the same be a focused electron F, which impinges within the focal area of the anode, or a stray electron M, which impinges upon the marginal portions of the anode surface S outwardly of the focal area, generates X-rays in the manner illustrated in Fig. 1; and such X-rays in the aggregate will include not only rays having the spectral characteristics of the electron target material of the anode within the focal area, but also the spectral characteristics of the anode material outwardly of its said target area.

In using X-rays for diffraction analysis, as shown more particularly in Figs. 2 and 3, a baffle or screen B of substantially X-ray opaque material may be employed in conjunction with the anode, said baffle preferably enclosing the anode on all sides thereof and having an aperture or opening O, usually configurated as a perforation or slit in the baffle. Such a baffle may control the emission of a sharply defined useful ray beam X through the baffle aperture O, which beam may be applied for the diffraction analysis of a material sample W to be analyzed. If desired, the analyzing beam X may be delivered upon the test sample W through Brentano slit apparatus or like means R for excluding all rays in the beam X which are not within a ray dispersal cone of limited angular divergence.

As shown more particularly in Fig. 3, a beam X produced in the foregoing manner, from an X-ray generator embodying a conventional anode of the sort shown in Figs. 1, 2, and 3, will not only include X-rays P, shown in solid lines in Fig. 3, generated as the result of electron impingement upon the focal area of the anode, such rays P consequently having the desired spectral characteristics of the target material comprising said focal area, but the ray X may also include undesirable rays Q, shown in dotted lines in Fig. 3, produced through impingement of stray electrons M upon the anode surface S outwardly of the focal area and hence providing undesirable spectral characteristics in the ray beam X, where the material of the anode outwardly of the focal area is of a sort having undesirable spectral characteristics.

To illustrate the present invention, Figs. 4–8 show an X-ray generator **11** comprising a sealed and evacuated envelope **12** containing an anode **13** and a cathode structure **14** having a head **15** in facing relationship with the anode within the envelope. The cathode embodies an electron emitting element **16**, which may comprise an elongated filament adapted to be electrically excited for the emission of electrons, as by electrically connecting the filament with a suitable source of exciting power outwardly of the envelope, the filament, to that end, being electrically connected with conductors **17** extending outwardly of the envelope **12**, through suitable conductor seals, and electrically connected, as with terminal means **18** formed or supported on the envelope for electrical connection with an external power source.

It will be noted that the preferably elongated emission element **16** is supported in a groove **19** formed in the head **15**, whereby electrons, emitted by the filament, when energized, will be focused upon an elongated area of the cathode facing portions of the anode **13**. To aid in thus focusing the electron stream upon the anode, the cathode structure may include a skirt-like baffle or shield **20** electrically connected with and projecting from the head **15**, in position encircling and enclosing the facing end of the anode. It is desirable, thus, to focus or concentrate impinging electrons as sharply as possible within what may be termed the focal area of the target surface of the anode, in order that generated X-rays may emanate from such well defined focal area and thereby allow for the production of useful X-ray beams of sharp definition.

The anode **13** may comprise a metal body **21**, as of copper or other suitable material, supported on the envelope **12**, as by means of a mounting **22**, the body having a stem **23** extending outwardly of the envelope. The body **21** is supported in the envelope in position presenting an end of the body in spaced facing relationship with respect to the cathode, and the anode may include a head **24** integrally united with the body **21**, at its cathode facing end, said head comprising any suitable or preferred target material and providing electron receiving target surfaces facing toward the cathode.

Any suitable or convenient source of external electrical power may be employed to cause electrons emitted by the element **16** to travel toward and impinge upon the target surfaces of the anode head **24**. To this end, said external power source may be electrically connected between one of the conductors **17** and the projecting stem portion **23** of the anode, outwardly of the envelope, in order to apply electron driving potential between the electron emission element **16** and the anode head **24**, said head being electrically connected with the body **21** and the portion **23** thereof which extends outwardly of the envelope.

X-rays generated at the target end of the anode as a result of electron impingement thereon may travel in all directions radially outwardly of the target. In the interests of safety, it is desirable to permit only such rays as are required for use to escape outwardly of the envelope. To this end, the envelope **12** preferably, though not essentially, may comprise glass which is substantially impervious to X-rays, in order to prevent egress of unusable or unwanted X-rays outwardly of the envelope **12**.

In order to insure the retention of unwanted X-rays, an annular sleeve **29** may also be provided in position surrounding the envelope **12** opposite the electron receiving end of the anode, said sleeve comprising material opaque to X-rays for the purpose of confining unwanted rays within the envelope. It is desirable, however, to allow all useful X-rays to have substantially unhampered exit from the X-ray source. To this end, the envelope may be formed with drawn necks **30**, providing envelope open-

ings angularly displaced around the envelope with respect to the target portions of the anode; and the skirt-like shield **20** may be formed with openings or slits **31** in alinement with the envelope openings defined by the necks **30**, the shield **20** being preferably supported on the cathode head in position presenting said slits **31** substantially in the plane of the focal spot area **25** of the anode, to permit the rays of a divergent X-ray beam **32**, generated as the result of electron impact on the focal spot area **25**, to pass outwardly of the envelope in unimpeded fashion through the slit or slits **31** and the envelope openings defined by a neck or necks **30** of the envelope.

The space within the envelope, of course, is necessarily maintained at low pressure, and, in order to seal the envelope at the openings defined by the necks **30**, suitable X-ray pervious window panes **33** may be sealed on the necks in position closing the openings defined thereby. Such X-ray pervious panes may comprise disks or plates of material, such as beryllium, which is substantially transparent to X-rays.

The divergence of ray beams employed in diffraction analysis normally ranges up to about four angular degrees. As heretofore shown, slit systems, which permit such divergent ray beams to reach a diffraction analysis sample, from anodes of conventional configuration, must necessarily allow radiation to reach the sample from electron impact stations or areas of the anode outwardly of the focal spot area, in addition to those rays which originate from the focal spot area itself.

For purposes of accuracy and precision in X-ray diffraction analysis, it is desirable to apply, to the body being examined, only such X-rays as originate at the focal spot of the anode, and exclude such rays as may be generated by electron impingement on the anode target areas outwardly of the focal spot or area. Since it is virtually impossible to so focus electrons, emitted from the element **16**, as to insure impingement of all emitted electrons only in the focal spot area, it is obvious that at least some of the electrons emitted by the element **16** will strike upon the anode portions outwardly of the focal spot area, and result in the generation of so-called off-focal spot radiation at the places or stations of impact of electrons, such as the electron **26'**, on the anode outwardly of the focal spot area. The present invention has for its principal object the provision of means whereby such off-focal spot radiation may be prevented from reaching a diffraction analysis specimen through a divergent ray beam slit system, even where divergence is of an order as large as ten angular degrees.

To this end, the anode head **24** is provided with a central focal spot area **25**, which comprises a flat target surface disposed preferably at right angles to the axis of a beam of electrons **26** emitted by the element **16**, although the principles of the present invention may, of course, be applied in X-ray generators in which the focal spot area of the anode is disposed in a plane other than normal with respect to the electron beam emitted by the cathode. Where the emission element **16** is of elongated configuration, the focal spot area **25** may be of corresponding, substantially rectangular, elongated configuration, although the invention, of course, is not necessarily limited to the marginal shape or configuration of the zone or area **25**, which may have circular, oval or other shape, if desired.

Immediately outwardly of the flat anode target surface forming the focal area **25**, the anode is formed with surfaces which extend away from the cathode in such fashion that all anode portions outwardly of the focal area lie behind planes extending at angles of the order of 15° or more with respect to the plane of the focal area. As shown, the anode surface portions outwardly of the zone **25** may comprise a pair of oppositely sloping surfaces **27** extending at and outwardly of the zone **25**, on the opposite sides thereof, and a pair of oppositely sloping surfaces **28** extending at and outwardly of the opposite ends of the zone **25**. The cathode facing portions of the anode head **24** thus comprise a body of truncated pyramidal configuration, consisting of the apexial surface area **25** forming the focal area of the anode target and the pyramidal side surfaces **27** and **28** outwardly of the apexial area and sloping at angles of the order of 15° or more in a direction away from the electron emission element **16** of the cathode. The invention, however, is not necessarily limited to the pyramidal configuration of the anode head, but, in its broader aspects, may include the formation of the head **24** as a truncated element of conical configuration providing a target area of circular or oval shape. Indeed, the anode surfaces, immediately outwardly of the target zone, may if desired include portions extending at any desired inclination with respect to the plane of the target area in excess of 15°.

The divergent ray beam **32**, produced by impact of electrons comprising the focused beam **26** upon the focal spot area **25**, may thus be delivered through the slit **31** and thence outwardly of the envelope **12** through a window pane or panes **33** substantially without obstruction. Any rays, such as the rays **34** generated at and emitted by the anode as the result of electron impingement upon the marginal anode surfaces outwardly of the focal area **25**, will not be transmitted through the slit **31** in a direction coincident with the path of the ray beam **32**, since such marginal surfaces diverge from the plane of the focal area at angles preventing emission of the rays **34** in the direction of the useful ray beam **32**.

In this connection, it should be understood that the angle of divergence of the inclined target surface portions of the anode outwardly of the focal spot area **25** need be only sufficiently large as to assure that all rays generated through electron impact on the anode, outwardly of the focal spot area, be emitted from the anode in a direction other than within the zone occupied by the useful divergent ray beam **32**. The invention, accordingly, is not necessarily limited to a particular inclination or shape of the anode surfaces outwardly of the focal spot area **25**, so long as anode configuration outwardly and rearwardly of the focal area is such as to accomplish the desired result.

The anode head **24** may, of course, comprise any desired target material, such as tungsten, molybdenum, copper, nickel, cobalt, iron, chromium, or other suitable target material, the choice of a suitable target material for X-ray diffraction analysis depending upon the type of specimen to be examined, the particular technique employed, and the sort of information sought.

In the interests of economy, the head **24** may be formed of copper or other relatively inexpensive target material, and a plate or button **35** of a desired, relatively expensive target material, such as tungsten, may be enveloped or otherwise secured in the material of the head **24**, in position exposed at the focal spot area **25** of the anode head. In such an arrangement it is desirable to form the button **35** so that it may include marginal target surface portions **36** extending outwardly of the central focal area **25**. Such an arrangement will result in producing a useful ray beam **32** having spectral characteristics corresponding only with the material of the button **35**, and excluding unwanted rays **34** having the spectral characteristics of the anode material forming the head **24** outwardly of the button **35**.

The inclination of the surfaces **27** and **28** is not critical so long as such surfaces are disposed at inclinations greater than the angle at which none fo the rays **34** extend within the useful beam **32** at the zone or station where the same is applied to perform a useful function, as at the slit means R, or at the specimen W under examination in the event that the useful beam **32** is applied directly to the specimen.

As shown more especially in Fig. 9, the inclined surfaces **28** may make substantial angles with respect to the target surface **25**, thereby providing a shouldered configuration

at the cathode facing end of the anode. In like fashion the surfaces **27** may make substantial angles with the target surface **25**. Indeed, if desired, the surfaces **27** and **28** may extend at right angles with respect to the target surface **25**.

Figs. 10 and 11 show that the invention, if desired, may be incorporated in an anode having a cathode facing end of generally circular configuration.

The above described anode structure has manifold advantages, especially where employed in X-ray generator tubes for diffraction analysis in accordance with the Brentano parafocusing technique. Anodes embodying the present invention provide greater spectral purity, especially when the target surface as is commonly the case comprises a target button **35** of the selected target material surrounded by another and different metal comprising the remaining portions of the head **24**. Greater spectral purity is also attained by minimizing the apparent intensity of tungsten radiation in the spectrum of rays emitted by the anode, the tungsten spectrum resulting from deposits of such metal upon the anode outwardly of the focal area **25** as the result of evaporation of the usually tungsten filament **16** during the service life of the generator tube. The present invention thus substantially reduces background aberration in the spectrum of rays produced by the operation of the tube, and thus narrows the base of diffraction lines and produces diffraction patterns of higher contrast and resolution.

It is thought that the invention and its numerous attendant advantages will be fully understood from the foregoing description, and it is obvious that numerous changes may be made in the form, construction and arrangement of the several parts without departing from the spirit or scope of the invention, or sacrificing any of its attendant advantages, the form herein disclosed being a preferred embodiment for the purpose of illustrating the invention.

The invention is hereby claimed as follows:

1. An X-ray generator tube comprising an anode having a target end, a cathode spaced from and facing the target end of the anode, and a sealed, evacuated envelope enclosing said anode and cathode, the target end of said anode providing a focal surface lying in a flat plane for receiving the impact of electrons emitted by the cathode of the tube, baffle means formed with an aperture slit therein for defining and transmitting, outwardly of the anode and substantially in the direction of the plane of said focal surface, a beam of X-rays subtending an angle of not more than 10° at the center of said focal surface, said anode having peripheral target portions extending at and outwardly of the marginal edges of said focal surface and lying entirely behind a plane intersecting the marginal edge of said focal surface at an inclination, with respect to the plane thereof, such that X-rays generated by electron impact upon said peripheral target portions will be emitted thence in directions other than coincident with the beam of X-rays delivered through said slit.

2. An X-ray generator tube comprising an anode having a target end, a cathode spaced from and facing the target end of the anode, and a sealed, evacuated envelope enclosing said anode and cathode, the target end of said anode providing a focal surface lying in a flat plane for receiving the impact of electrons emitted by the cathode of the tube, and baffle means forming an aperture slit therein for defining and transmitting, outwardly of the anode and substantially in the plane thereof, a beam of X-rays emitted at said focal surface and subtending an angle of 5° or less, said anode having peripheral target portions extending at and outwardly of the marginal edges of said focal surface and lying entirely behind a plane intersecting the marginal edge of said focal surface at an inclination, with respect to the plane thereof, such that X-rays generated by electron impact upon said peripheral target portions will be emitted thence in directions other than coincident with the beam of X-rays delivered through said slit.

3. An X-ray generator tube comprising an anode having a target end, a cathode spaced from and facing the target end of the anode, and a sealed, evacuated envelope enclosing said anode and cathode, the target end of said anode providing a focal surface lying in a flat plane for receiving the impact of electrons emitted by the cathode of the tube, and a baffle in position screening said anode and formed with an aperture slit for defining and transmitting, outwardly of the anode and substantially in the direction of the plane of said focal surface, a beam of X-rays subtending an angle of the order of 5° at the center of said focal surface, said anode having peripheral target portions extending at and outwardly of the marginal edges of said focal surface and lying entirely behind a plane intersecting the marginal edge of said focal surface at an inclination, with respect to the plane thereof, such that X-rays generated by electron impact upon said perpiheral target portions will be emitted thence in directions other than coincident with the beam of X-rays delivered through said slit.

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