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3,012,163

DEMOUNTABLE X-RAY TUBE

Filed April 9, 1959

3 Sheets-Sheet 1

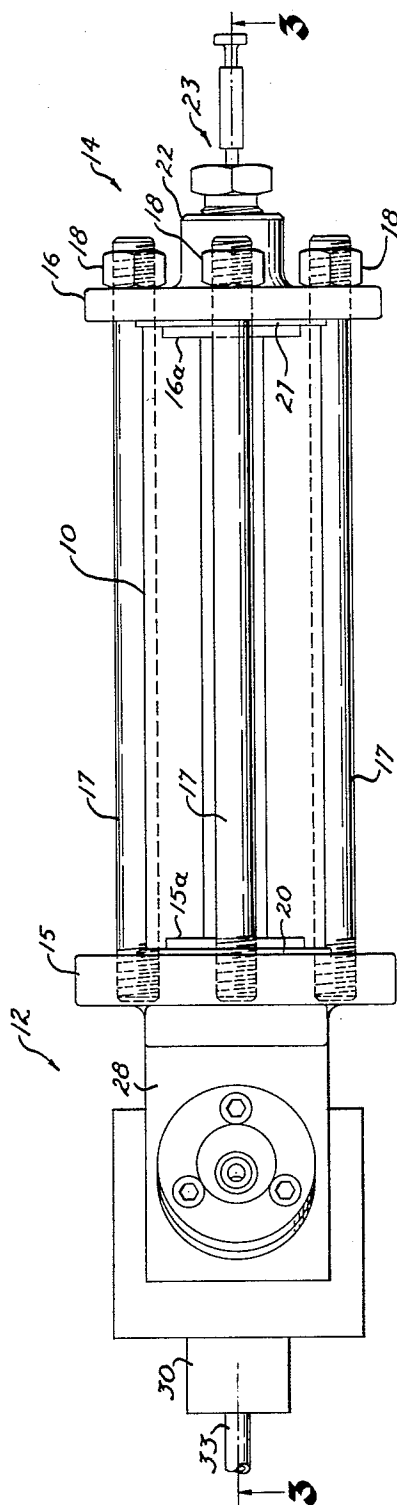


Fig. 1

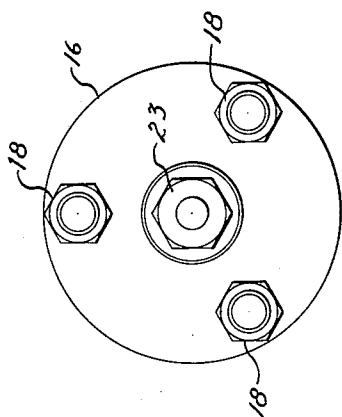


Fig. 2

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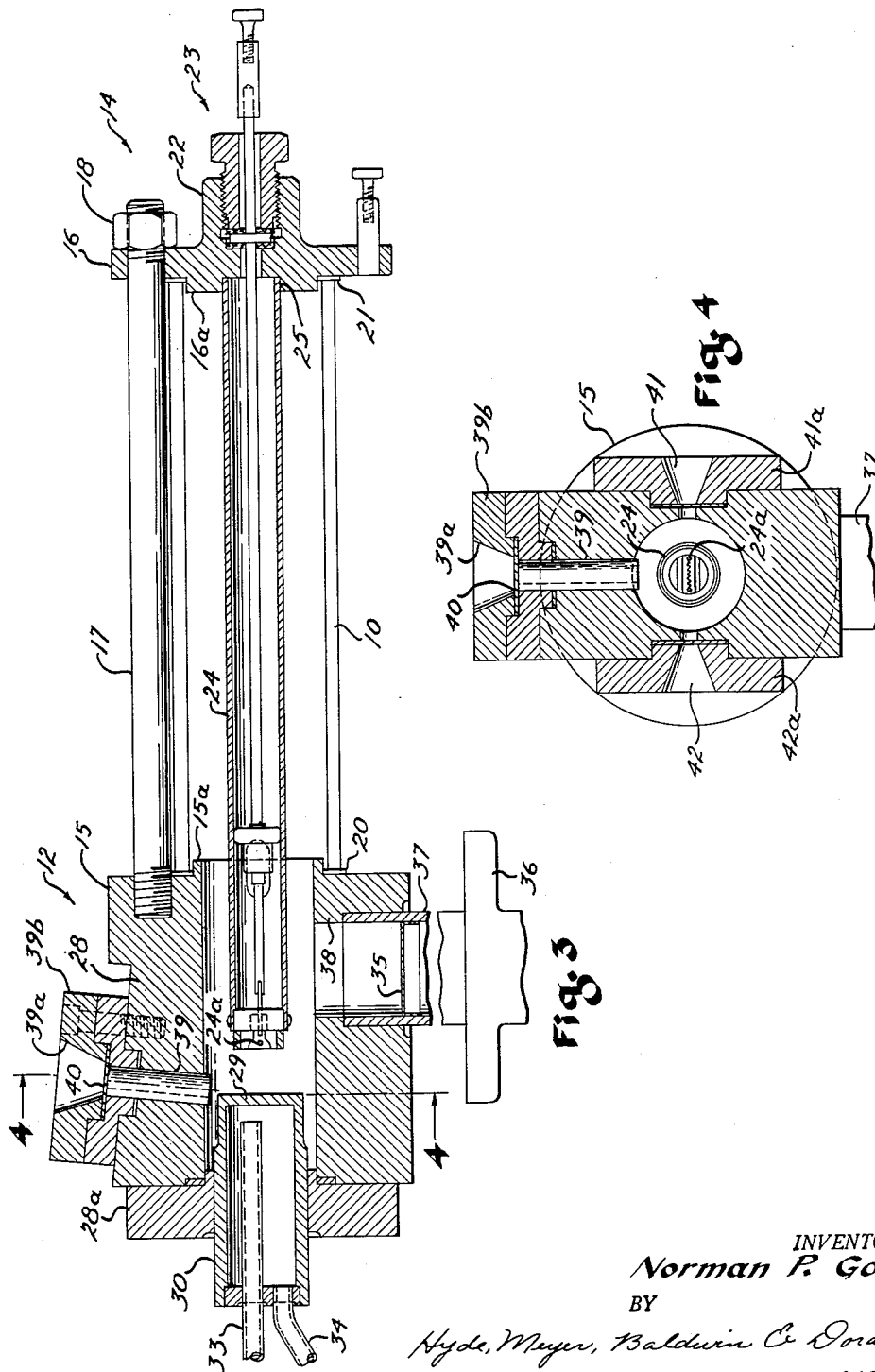
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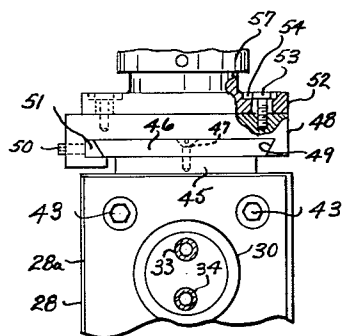
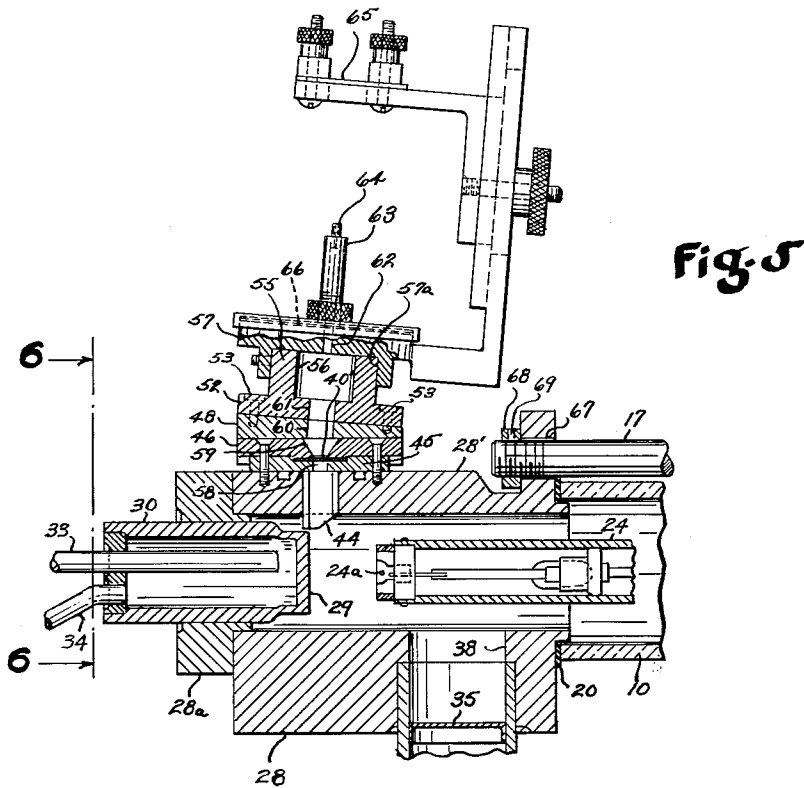
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3,012,163

DEMOUNTABLE X-RAY TUBE

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6 Claims. (Cl. 313—57)

This invention relates to a demountable X-ray tube of the continuously evacuated type and more particularly to a fine focus X-ray tube.

An object of the present invention is to provide a demountable X-ray tube which can be easily disassembled from its supporting structure and yet when assembled remain capable of producing a vacuum substantially as good as a permanently sealed tube.

Another object of the present invention is to provide a mounting for an X-ray tube having the characteristics of a permanently sealed tube while permitting fine focusing of the tube by external adjusting means.

Another object of the present invention is the provision of a combined mounting for an X-ray tube and a cassette wherein fine line focusing is provided in the tube so that the emitted rays may pass accurately into a slit system, part of which is in the tube housing or mounting and part of which is in the camera itself, and means is provided between the camera and tube mountings so that the mere positioning of the cassette on the tube housing accurately aligns the two parts of the slit system.

Still another object of this invention is to provide a demountable X-ray tube of the continuously evacuated type wherein means are provided between the tube housing and a vacuum pump to prevent the tube filament from becoming carburized resulting from the oil of the pump diffusing into the tube housing.

Another object of the present invention is to provide a demountable X-ray tube characterized by its structural simplicity, the ease of assembly of its parts, its strong and sturdy nature and its low manufacturing cost. Other features of this invention reside in the arrangement and design of the parts for carrying out their appropriate functions.

Other objects and advantages of this invention will be apparent from the accompanying drawings and the following description, and the essential features will be set forth in the appended claims.

This application is a continuation-in-part of my co-pending application Serial No. 504,633, filed April 28, 1955 for "Metal X-Ray Tube."

In the drawings:

FIG. 1 is a top plan view of my novel X-ray tube;

FIG. 2 is an end elevational view, as seen from the right-hand side of FIG. 1;

FIG. 3 is a vertical view taken along the plane of line 3—3 of FIG. 1;

FIG. 4 is a transverse sectional view taken along the plane of line 4—4 of FIG. 3;

FIG. 5 is a sectional view through my improved X-ray tube showing a modification of the left end of FIG. 3 and intended for use with the right-hand portion of the device shown in FIG. 3; while

FIG. 6 is a fragmental end elevational view taken along the line 6—6 of FIG. 5.

The present invention is directed to providing a novel demountable X-ray tube which is capable of being quickly adjusted after assembly so that the cathode and anode portions of the tube may be finely focused to cause the cathode rays to hit the exact center of the anode or target area.

Referring now to FIG. 1, I have shown an elongated hollow tubular glass housing 10 which has its ends supported by a pair of spaced end members 12 and 14, of which 12 is a massive metal block and 14 is a rigid end

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cap. Each of the end members 12 and 14 is provided with an enlarged annular rim or flange portion 15 and 16 respectively. Each of the flange portions 15 and 16 has a diameter substantially greater than that of the tubular glass housing 10 and thereby they are adapted to receive a plurality (three being shown) of rods or bolts 17 of electrically insulating material, such as Bakelite, which are equally spaced circumferentially about the exterior of the tube 10. Each of the bolts is threaded at both ends, one end of which threadedly engages flange member 15 while the other end projects freely but snugly through flange member 16. The free end of each bolt is provided with an adjustable nut 18 which is tightened down to a point where it abuts the outer surface of flange 16 and thereby forms a rigidly connected unit or envelope of the two end members 12 and 14 and the tubular glass housing 10. Since it is essential to have a high vacuum when operating electron type X-ray tubes, deformable sealing means are provided between the tubular glass housing and flange members 15 and 16. The deformable sealing means here take the form of annular rubber gaskets 20 and 21 as best seen in FIG. 3, which are inserted over the raised annular portions 15a and 16a of the end flanges 15 and 16 respectively and are held under pressure between the ends of tube 10 and the end flanges 15 and 16 by bolts 17 and nuts 18. The pressure on the rubber gaskets 20 and 21 is controlled directly by the amount nuts 18 are tightened. The equal circumferential spacing of the three bolts 17 permits an even pressure to be exerted upon the annular gaskets. It also aids in directing the electron beam (cathode rays) toward the anode as will presently appear. Although I have found rubber gaskets work satisfactorily, it is not my intention to limit the present invention to such gaskets since any suitable deformable material may be used. The vacuum produced in the present device far exceeds that of the prior art. The improvement lies in the sealing means which prevents tube leakage in turn requiring less pumping effort to maintain the vacuum. In most demountable tubes prior to the present invention, the filament life was only one to fourteen days. In the present construction, the filament life is greatly increased. Filament life in the present tube is of the order of 2000 hours. Inferior sealing means caused leakage which permitted rapid deterioration of the filament in most demountable tubes prior to the present construction. In the prior devices, the sealing means was usually a wax joint and proved to be very unsatisfactory.

The right end member 14, as viewed in FIG. 3, rigidly supports the cathode or filament containing tube 24 in a recessed bore 25 provided in the annular raised portion 16a. The filament portion of the cathode tube may be adjusted by suitable means 23 threadedly engaging the elongated sleeve portion 22 of the end member 14. The cathode supporting tube 24 extends substantially coaxially through the tubular glass housing 10 and projects into a central hollow bore 27 contained in the opposite end member 12. The end member 12 includes a substantially rectangular housing 28 which is somewhat longer than it is wide and is integrally connected with the annular rim or flange portion 15. This structure forms no part of the invention and therefore will not be described in detail. The housing 28 supports the anode or target portion 29 of the X-ray tube. The anode may be of any known form, but here comprises a copper tube 30 closed at both ends, and inserted through the closed end 28a and projects into the central bore 27 of end member 12. The inner closed end of the tubing 30 supports the workpiece which is to be examined. The electron stream produced from the cathode 24a is directed against this metal target which emits the X-rays in the usual manner. To permit continu-

ous operation with large space current, water or other cooling fluid is preferably circulated within the target tube 30 to dissipate the heat generated. For this purpose I have provided inlet and outlet copper tubes 33 and 34 respectively, which are connected to a suitable fluid reservoir and pump, not herein shown.

In order to obtain the best results from this type of X-ray tube, it is necessary that the electron stream be directed at the center of the target. It is also essential that a high vacuum be produced within the tube. Prior to my invention, it was impossible to adjust the position of the cathode tube 24 without the risk of breaking the seal between the glass electrode 10 and its associated end members 12 and 14. However, with the present device, it is possible by tightening one or two of the circumferentially equally spaced nuts 18 as viewed in FIGS. 1 and 2, to cause end member 14, tubular housing 10 and cathode tube 24 to be tilted axially in the direction of the nuts so tightened. Such tilting is accommodated by the resiliency of the annular rubber gaskets 20 and 21 which compress slightly in the areas so tightened. Should there be any tendency for the side opposite that which is tightened to become slightly loosened due to the tilting effect away from that side, the seal will remain perfect due to the inherent resilient nature of the rubber gaskets which will expand to accommodate such tensioning action. Thus, a good seal, beyond that possible on demountable tubes of the prior art, is maintained at all times. It will be readily seen that through the provision of three equally spaced bolts 17, it is possible to attain any desired movement in any direction of the free end of cathode tube 24. It will be understood that the movements referred to are of a relatively small nature. However, it will be readily seen that a very slight movement of the end member 14 which rigidly supports the cathode tube 24 will cause a relatively larger movement at the opposite free end of the cathode tube or that end which is adjacent the anode target area 29. It is possible with the present novel construction to maintain a vacuum substantially as good as that produced in permanently sealed glass tubes, while simultaneously aligning the cathode tube so that its stream of electrons will be directed to hit the exact center of the target area. It is thus possible to use a fine line focus (.015 inch by $\frac{3}{4}$ inch). This makes it possible to operate the tube at a lower current input while simultaneously having the advantage of a high intensity beam of X-rays.

To take advantage of the fine line focus, focal spot on the target, a slit system is incorporated into the body of the tube. Part of the slit system is in the body of the tube while the other part is incorporated in the film specimen holder portion of an X-ray cassette, as shown in FIG. 5. The slit system which includes passages 39, 41 and 42 is accurately aligned with the target so that the X-ray beam can be precisely passed into the system. (In the back reflection cassette, for example, the slit system may consist of two pin holes spaced about ten centimeters apart. This provides a nearly parallel X-ray beam required for certain kinds of metallurgical investigations.) A portion of each slit, such as 39, is in the tube body, as indicated in FIG. 3, while the remainder of the slit is on the film holder which would be mounted on 39b and when in position is in exact alignment with passage 39. Cassettes or cameras for various investigations are mounted on the projections 39b, 41a and 42a, provided on the body of the tube. The camera or cassette which contains the remainder of the slit system and is mounted on 39b and 42a may also be provided with some adjustment for slit alignment if desired. In this way, exacting slit alignment is made with the focal point (fine line focus) on the target of the tube to permit the electron beam to enter through the shutter of the camera and impinge upon a film contained therein. In other words, the heavy block 12 forming the end member gives a rigid unitary positioning means for the target, tube 39 and the camera-supporting bracket 39b.

To further illustrate the specific combination of a slit system partly in the tube mounting and partly in the cassette, I have shown such details in FIGS. 5 and 6. Here the block 28' performs the same functions as the block 28 in the first described form and the glass tube 10 is held between block 28' and a cap member 14 at the opposite end by means of three spaced dielectric bolts 17 with resilient gaskets 20 and 21 between the closing members at opposite ends of the tube 10 so as to tightly seal the tube against the end members which close the opposite ends of the glass tube 10. The member 24 which carries the filament 24a at its inner end is constructed as before and all of the parts not shown in FIG. 5 are built the same as those described in connection with FIG. 3. The target 29 is like that previously described and is rigidly carried by a block 28a which is demountable from the block 28' by means of the holding screws 43.

Here the slit system in the block 28' comprises two generally channel-shaped members 44 mounted in a suitable opening in the block 28'. These two channel-shape forms enclose between them a slit which may be approximately $\frac{1}{4}$ inch as seen from left to right in FIG. 5 and which in the dimension crosswise of that or in the direction perpendicular to the paper in FIG. 5 would be from about .002 inch to .080 inch, the more widely used slit generally being .020 to .040 inch in the lateral dimension just mentioned. It will be noted that the slit system extends as close to the focal point on the target 29 as possible.

The mounting for the cassette comprises a block 45 rigidly secured by screws (not shown) to the block 28' and having on its upper face a gib plate 46 rigidly secured to block 45 by screws 47. A sliding plate 48 is provided with parallel ways 49 to receive the gib plate 46 so that plate 48 may be slidingly adjusted longitudinally of the X-ray tube axis. This adjustment is locked by means of one or more screws 50 which press a wedge-shape member 51 against the gib plate 46 to hold the parts in the desired position.

Another adjustment is provided at right angles to that just described by means of a second plate 52 mounted to slide on top of the plate 48 and adjustable at right angles to the main axis of the X-ray tube by means of screws 53 which pass through slotted openings 54 in the plate 52 and are threaded into the block 48. The plate 52 has provided rigid therewith an upstanding cylindrical flange 55 which is preferably bored out at 56 to receive one type of cassette or camera connector and which on its outer diameter is adapted to be a snug fit with a cassette holder 57 such as is shown in position in FIG. 5. The hollow collar 57a extending downwardly from the cassette holder is a snug fit on the flange 55 so that it is merely necessary to assemble the parts together as shown in FIG. 5 to have an accurate mounting of the cassette holder or camera on the tube housing. These parts are so rigid and so snugly fit together that they accurately position the parts of the slit system about to be described. Opposite the slit formed by the members 44 previously described there is an opening 58 in plate 45 which is provided with a window 40' which is analogous to the window 40 of FIGS. 3 and 4. A flared opening 59 is then provided in gib plate 46 aligned with the opening 58. Further aligned openings 60 and 61 are provided in the plates 48 and 52 respectively to continue the slit system. The cassette holder has a central opening 62 in alignment with the openings 60 and 61 and this in turn is aligned with a tubular extension 63, the upper end of which is usually provided with a plug 64 having a very fine central opening so as to provide a beam of parallel rays extending upwardly toward the sample to be treated with the X-rays indicated at 65 in the sample holder. Those familiar with this art will understand that a film 66 is held in the cassette holder when operating and shutter means is provided in the cassette holder to

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provide an exposure, this arrangement not being illustrated more fully because it is well known.

It will be apparent from the above description, that one may obtain a fine line focus by the movement given to the member 24 adjusting the three nuts 18 as previously described and that this may pass out through a slit system in the block 28' and through the slit system 62, 63, 64 in the cassette either with or without the adjustments described in connection with the ways 49 and the slotted openings 54. However, with these two additional adjustments at right angles to each other provided by ways 49 and slotted openings 54, a still finer adjustment of the slit system is possible.

It will be noted that there is an inclined surface between the plates 48 and 52. This is to set the slit system at the optimum angle of between 5 and 10 degrees as the electrons are emitted from the target 29 as is well known in this art. The openings 44, 58, 59, 60, 61, 62, 63 and 64 are of sufficient size and so aligned that the beam of X-rays may pass through the entire system when the parts are aligned.

I have shown in FIG. 5 the possibility of a still closer adjustment of the filament 24a than that which is possible in the form shown in FIGS. 1 and 3. Here, bolt 17, shown in FIG. 5, which lies in a plane at right angles to a plane through the elongated filament 24a is caused to pass freely through an opening 67 in the block 28' and is provided with an adjusting nut 68 on the threaded end of the bolt 17. This nut may be provided with a small opening 69 to receive a pin by which the nut 68 may be slightly rotated on the bolt 17. In the use of this improvement, the usual adjustment is made using the nuts 18, as previously described, and then after the tube is supplied with high tension current (after which the nuts 18 cannot be touched because of the high tension), then the nut 68 may be given a very fine adjustment to give an extremely fine focus of the filament relative to the target and relative to the slit system above described.

If the filament gives a point focus on the target, a plurality of the bolts 17 could be provided with the adjusting nuts 68.

The present invention is also directed to protecting the filament 24a against deterioration from the effect of oil in the vacuum system through the provision of a novel filter element 35 located between the X-ray tube and the vacuum pump. Only the connecting flange 36 of the vacuum pump is shown. A pipe 37 communicates between the pump and the interior of the tube 10 through bore 38 provided in the side walls of the housing 28. I am able to provide a nearly perfect vacuum and the use of filter 35 increases the filament life and current stability of the X-ray tube. The filter may comprise, for instance, a circular copper screen of approximately 16 meshes to the inch which is of a size to fit snugly within the connecting pipe 37. The screen is preferably covered with a flocking of cotton or like fibrous material for the purpose of absorbing any oil vapors and preventing them from self diffusing into the X-ray tube chamber from the pump. If the oil vapor were permitted to contact the tungsten filament of the cathode tube which operates at a high temperature, it would cause the filament to carburize and thereby rapidly destroy the filament. A plurality of these filters may be used in the connecting pipe 37 if desired without greatly reducing the pumping efficiency due to the very porous nature of the filter element.

The passageway 39 which extends downwardly through the upper surface of the housing 28 permits exit of the X-ray beam through a flared end opening 39a. The passageway 39 incorporates the slit system and a beryllium, aluminum or mica window 40. The features present in my novel demountable tube make it comparative in operation to the more expensive permanently exhausted tubes. Permanently exhausted tubes have serious shortcomings when used as soft X-ray radiation sources, since the win-

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dows become coated with a film of tungsten, caused by evaporation from the filament. This shortcoming is substantially eliminated in the present novel tube construction. The tungsten which is evaporated cannot be spattered on the beryllium window since the passageway 39 in the X-ray beam defining means is often $\frac{1}{8}$ inch in one dimension and .040 to .080 inch in the other dimension. The tungsten vapor does not diffuse easily into so small an opening. The passage 39 is of considerable length, approximately $1\frac{1}{2}$ to 2 inches from its lower end to the window 40, and tungsten finding its way into it will be deposited mostly on the side walls of the passage. A line drawn through the center of the passage 39 intersects a line drawn through the center of the target tube 30 on the target portion or surface 29. The lower end of passage 39 is within approximately $\frac{1}{2}$ inch of the center of the target. It should be further pointed out that the present construction prevents undue heating of the window. Prior tubes usually were provided with water-cooled windows, whereas the present tube is of such a massive construction that it does not become unduly heated in operation. Any heat acquired by the body is uniformly distributed throughout the body. It is, however, necessary to cool the target in order to prevent undue or excessive heating of the tube. This is done by circulating water or other coolant fluids through the pipes 33 and 34 as heretofore explained. Uniform heating results in preventing excessive air leaks at the various seals.

Cameras or cassettes (not herein shown) may be mounted as heretofore described to record pictorially the effect of the X-rays on the target 31 through flared windows 39a, 41 and 42 which are provided in the side walls of projections 39b, 41a and 42a, as seen in FIG. 4. In chemical analysis work the target would be the specimen. However, in general X-ray work the target is only used as an X-ray source; the specimen is mounted in the cassette (not shown) which would be mounted on 39b and 42a.

In view of the foregoing description, taken in conjunction with the accompanying drawings, it is believed that a clear understanding of the construction, operation and advantages of the device will be quite apparent to those skilled in this art.

It is to be understood, however, that even though there is herein shown and described a preferred embodiment of the invention, the same is susceptible to certain changes fully comprehended by the spirit of the invention.

What is claimed is:

1. In a demountable X-ray tube comprising an envelope and an anode target and a cathode filament in said envelope, the combination of said envelope having an elongated hollow tubular member and a massive metal block end member closing one end of said tubular member and a cap end member closing the other end of said tubular member, there being a central recess in said block axially aligned with the hollow of said tubular member and opening axially toward the latter, an anode target carried by said block at the axially outer end of said recess, an elongated cathode support member rigidly carried by said cap end member and extending through said tubular member with its distal end in said recess and near said target, a cathode filament mounted at said distal end of said cathode support member, at least a portion of a slit system comprising a passage of narrow cross-section through said block from the outside thereof to said recess adjacent said anode target, bolt means generally parallel to the axis of said tubular member and engaging said end members laterally outside of said tubular member and firmly holding said block and said cap at opposite ends of said tubular member, adjustable securing means operatively connected between said bolt means and said cap end member to cause tilting of said cap and its associated cathode support member relative to the axis of said tubular member, there being deformable sealing means between said tubular member and at least

one of said end members, whereby selective adjustment of said securing means causes a slight tilting of said cap end member with a corresponding movement of said cathode filament, at the end of said cathode support member, relative to said anode target carried by said massive block, which provides a fine line focus of the cathode filament relative to the anode target so that the emergent rays pass exactly through said passage of narrow cross-section.

2. The combination of claim 1 wherein said bolt means are of dielectric material, said tubular member is electrically insulated from said end members, and said tubular member and said bolts are the only parts extending between said end members, whereby high voltage may exist between said anode and cathode while said X-ray tube is operating while still maintaining a small diameter of said envelope so as to shorten the distance between said anode target and a sample exposed to radiation through said passage.

3. The combination of claim 1 including an open passageway communicating between said envelope and a vacuum source, and an oil absorbing filter in said last named passageway preventing oil vapor diffusing from said source into said envelope.

4. In a demountable X-ray tube comprising an envelope and an anode target and a cathode filament in said envelope, the combination of said envelope having an elongated hollow tubular member and a block end member closing one end of said tubular member and a cap end member closing the other end of said tubular member, an anode target carried by said block, an elongated cathode support member rigidly carried by said cap and extending through said tubular member with its distal end near said target, a cathode filament mounted at said distal end of said cathode support member, at least a portion of a slit system comprising a passage of narrow cross-section through said block from the outside thereof to a point adjacent said anode target, bolt means generally parallel to the axis of said tubular member and engaging said end members laterally outside of said tubular member and firmly holding said block and said cap at opposite ends of said tubular member, adjustable securing means

operatively connected between said bolt means and said cap end member to cause tilting of said cap and its associated cathode support member relative to the axis of said tubular member, there being deformable sealing means between said tubular member and at least one of said end members, whereby selective adjustment of said securing means causes a slight tilting of said cap end member with a corresponding movement of said cathode filament, at the end of said cathode support member, relative to said anode target carried by said block, which provides a fine focus of the cathode filament relative to the anode target so that the emergent rays pass exactly through said passage of narrow cross-section, said bolt means including three bolts spaced 120 degrees apart around said tube axis, at least one of said bolts passing freely through a portion of said block end member, and a nut on the free end of said one bolt whereby an additional focal adjustment may be made after said tube is energized.

5. In a demountable X-ray tube comprising an envelope and an anode target and a cathode filament in said envelope, the combination of a rigid housing closing the anode target end of said envelope, a partial slit system leading from near said target through said housing, means providing a fine line focus for aligning an emitted beam from said target through said partial slit system, a cassette having a partial slit system, and coacting separable mounting means on said cassette and housing respectively for holding said partial slit system in alignment merely by engagement of said mounting means.

6. The combination of claim 5 including adjustable means supporting said mounting means on said housing, said adjustable means providing movement of said partial slit system of said cassette relative to said partial slit system of said housing.

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