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TEMPERATURE ENHANCED FIELD EMISSION X-RAY TUBE

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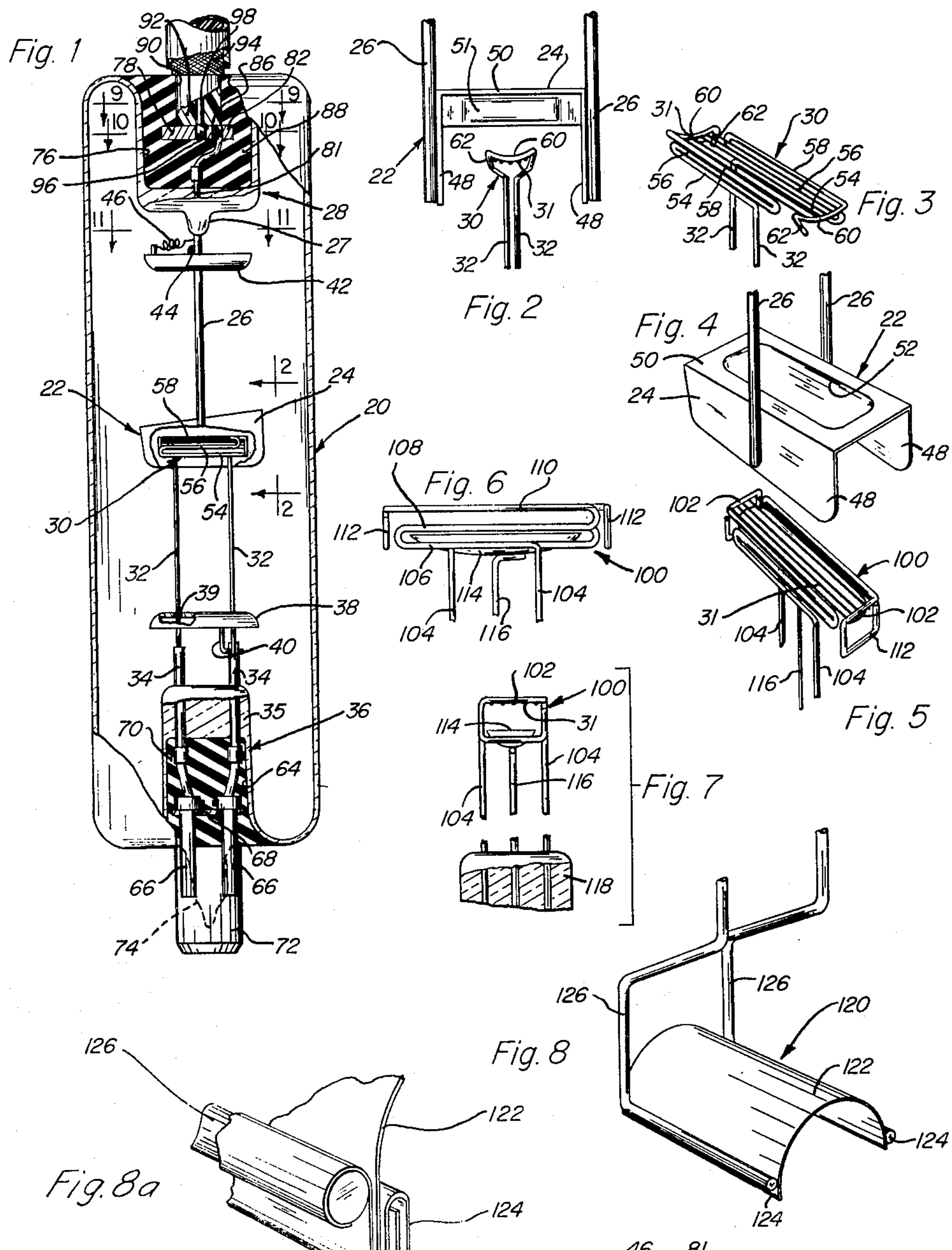

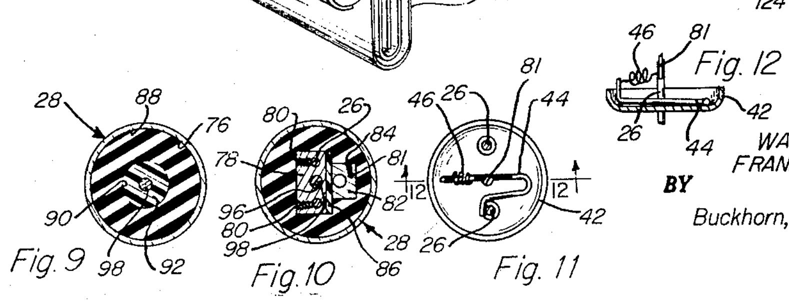

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TEMPERATURE ENHANCED FIELD EMISSION X-RAY TUBE

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This invention relates to a temperature enhanced field emission X-ray tube and more particularly to an X-ray tube adapted for pulse operation in which both thermal emission and field emission of electrons from a cathode structure are employed and in which an intense focused stream of high velocity electrons is caused to strike an anode during a short period of time by applying a narrow square wave pulse of high voltage across the anoded and cathode connections of the tube.

Tubes in accordance with the present invention have cathode and anode structures which are capable of being employed to produce and impinge upon the anode an intense focused beam of electrons traveling at high velocity to thereby produce high intensity X-rays. Electrons are emitted from the cathode by a combination of thermal and field emission and such emission may be of the order of 2000 to 4000 amperes per square centimeter of emitting surface. Sufficient emitting surface may be provided so that maximum currents, for example, of the order of 1000 to 2000 amperes may be produced in such tubes. Such current is produced for very short times, for example, times of the order of one-tenth to two-tenths microseconds. The spacing the anodes and cathodes is such that the maximum voltage applied thereacross may be of the order of 300 to 600 kv. and such that the tubes may have impedances of the order of 300 ohms. The maximum power applied to the tubes may therefore be of the order of 300 to 1200 million watts so that an intense source of X-rays is provided for a short period of time during each operation of the tube.

In tubes in accordance with the present invention, electron emission is from a plurality of cathode elements in the form of parallel heated wires of small diameter supported in a cathode structure. The cathode structure is constructed and positioned relative to an anode so that an electron beam from the cathode elements is focused upon a target area on the anode. In order to prevent undesired field emission of electrons from the supports for the cathode elements, such supports have their surfaces in the vicinity of the anode and directed toward the anode, carefully smoothed to avoid points or edges of small radius of curvature. Consistent repeated operation of such tubes requires that such surfaces remain in a smooth condition.

The tubes of the present invention are constructed so that the supports for the cathode elements are self-cleaning and self-smoothing if the tubes are properly operated. Thus any points or edges of small radius of curvature which tend to be produced on such supports due, for example, to sputtering of metal from the anode during operation of the tube are removed during operation of the tubes. In order to accomplish this, the supports for the cathode elements can be heated to self-cleaning and smoothing temperatures by heating currents during such operation of the tubes. The leads for the heating currents for the cathode elements provide the supports for such cathode elements and also provide electron beam focusing structure adjacent such cathode elements. Such leads are of a size relative to the wires forming the cathode elements that they are also heated to a relatively high temperature during operation of the tube. For example, in the case of tungsten cathode elements and leads, cathode elements may be heated by a heating current to

a temperature of 2900 to 3000° K. while the leads adjacent the emitting wires are heated to a temperature of the order of 1900 to 2000° K. At such temperatures, any impurities upon the surfaces of the leads are largely evaporated and the metal itself is self-smoothing by reason of surface migration of atoms thereon.

The voltage pulses applied between the anode and cathode of the tube are preferably sufficiently short that the voltage is removed before ions from the anode have reached the cathode structure to thus provide transit time isolation. Very little material is carried from the anode to the cathode and, if the surfaces of the leads directed toward the anode are originally made very smooth, the heating action referred to retains such smoothness.

The anode structure of the tubes preferably includes a thin plate formed to partially surround the cathode structure so as to prevent stray electrons from bypassing the anode and striking the tube envelope to thus damage the envelope or release contaminating gases therefrom. Such anode may, however, be sufficiently thick that substantially all of the usable X-rays are emitted from the surface directed toward the cathode. In the preferred anode structure, the area of the anode which is struck by the electrons is positioned on an embossed portion extending out of the general plane of any portion of the anode to provide stiffening ridges around such area. Alternatively the anode may be of thin enough foil so that usable X-ray emission is produced from the side of the anode opposite the cathode. Such foil anode may be semicircular shape in cross section as to partly surround the cathode and may be supported so that it also can be heated by passage of a heating current therethrough during out gassing of the electrodes of the tube. In this connection the tube is carefully outgassed by extensive heating and pumping and an effective getter is employed so that a vacuum of the order of 10^{-12} mm. of mercury is obtained. Also a glass for the envelope is selected which is substantially impervious to all gases including helium, so that such vacuum is maintained.

The anode and cathode structures of the present invention can be contained in tubes of relatively short length. When such tubes are subjected to the high voltages referred to above, flash overs tend to occur around the tube from the anode to the cathode connections. In accordance with the present invention, an anode connection has been developed which effectively prevents such flash overs. Such connection includes a reentrant portion in an end of the envelope of the tube which is filled with insulating material. The insulating material has a socket into which the end of an insulating sheath of a solid dielectric coaxial cable can be inserted after the outer conductor of the cable has been removed from such end. This eliminates any air path between the anode and cathode connections.

It is therefore an object of the present invention to provide an improved X-ray tube for pulse operation in which high currents can be produced for short lengths of time by the application of short pulses of high voltage so as to provide an intense X-ray output.

Another object of the invention is to provide an X-ray tube in which field emission enhanced by high temperature operation of a cathode of small radius of curvature is employed to produce high intensity short pulses of X-rays.

Another object of the invention is to provide a cathode structure for a temperature enhanced field emission X-ray tube in which a plurality of electron emitting elements of small diameter are heated to a thermal emission temperature by a heating current and are supported by leads which form part of an electron beam focusing structure and which are themselves heated by such current to a cleaning and smoothing temperature.

Another object of the invention is to provide a cathode structure for a temperature enhanced field emission X-ray tube in which the leads for a plurality of cathode elements supply heating current flowing through such elements and also form part of an electron beam focusing structure.

Another object of the invention is to provide an improved anode connection particularly useful with X-ray tubes for preventing flash overs between the anode and cathode connections of such tubes when high voltage pulses are applied between such connections.

A further object of the invention is to provide an improved structure for connecting a solid dielectric coaxial cable to an electrode of a tube in a manner which eliminates air paths for electric discharges around the envelope of the tube when high voltages are applied to such tube.

Other objects and advantages of the invention will appear in the following description of preferred embodiments shown in the attached drawing of which:

FIG. 1 is side elevation of an X-ray tube in accordance with the present invention with parts broken away to show internal structure;

FIG. 2 is a fragmentary end elevation on an enlarged scale of the anode and cathode structures of the tube of FIG. 1, looking in the direction of the arrows 2—2 of FIG. 1;

FIG. 3 is a perspective view of the cathode structure of FIGS. 1 and 2 on approximately the same scale as FIG. 2;

FIG. 4 is a perspective view of the anode structure of FIGS. 1 and 2 on approximately the same scale as FIG. 2;

FIG. 5 is a view similar to FIG. 3 of a modified cathode structure;

FIG. 6 is a fragmentary side elevation of the cathode structure of FIG. 5;

FIG. 7 is an end elevation of the cathode structure of FIG. 6, also showing the upper end of a seal for the leads supporting such cathode structure;

FIG. 8 is a perspective view similar to FIG. 4, showing modified anode structure and a detail of the connection of such anode to a supporting lead;

FIG. 8*a* is a fragmentary perspective view showing a detail of the structure of FIG. 8 on an enlarged scale;

FIG. 9 is a fragmentary horizontally cross section of the upper portion of the anode connection for the tube of FIG. 1 taken on the line 9—9 of FIG. 1;

FIG. 10 is a view similar to FIG. 9 taken on the line 10—10 of FIG. 1;

FIG. 11 is a view similar to FIG. 10 taken on the line 11—11 of FIG. 1 and showing a getter and shield structure for the anode seal; and

FIG. 12 is a vertical section of a getter and shield structure of FIG. 11 taken on the line 12—12 of FIG. 11.

Referring more particularly to the drawings, the X-ray tube of FIG. 1 includes a glass envelope **20** of any suitable form, for example, the cylindrical form shown, having an evacuated interior. An anode structure **22** positioned in such envelope includes a trough-shaped anode **24** of thin sheet metal and a pair of supporting leads **26**. The leads **26** pass through a press seal **27** forming part of a reentrant glass seal structure **28** at the anode end of the tube. A cathode structure **30** also positioned in the envelope **20** includes supporting leads **32** for an electron emitting portion of the cathode in the form of a plurality of parallel filament wires **31** extending between the leads. The leads **32** are connected to larger supporting leads **34** which pass through and are supported by another press seal **35** forming part of a reentrant glass seal structure **36** at the cathode end of the tube. The tube also contains a shield **38** for the seal structure **36**, which shield is supported from one of the leads **34** by a member **40**. The leads **32** extend through apertures **39** in the shield **38** so as to be out of contact with such shield. The tube also contains a shield **42** for the seal structure **28**, the shield **42** being supported from one of the leads **26** by a

support member **44** which also forms one terminal for a getter heater **46**.

The anode **24** of the anode structure **22** of FIGS. 1, 2 and 4 is of rectangular trough-shape conformation and has its side portions **48** secured to the anode supporting leads **26** in any suitable manner, for example, by spot welding. The side portions of the anode **24** extend past the electron emitting portion of the cathode structure so that the anode **24** surrounds three sides of such portion of the cathode structure. The intermediate portion **50** of the anode is rectangular and is spaced from the wires **31** forming the electron emitting portion of the cathode. Electrons from the cathode strike a central target area **51** of such intermediate portion and such portion is subjected to considerable temperature and electrical stresses. A portion corresponding approximately to the target area **51** is therefore preferably displaced out of the general plane of the intermediate portion of the anode **24** by an embossing operation as indicated at **52** in FIG. 4. This provides stiffening portions surrounding the target area of the anode. As shown in FIGS. 1 and 2, the intermediate portion of the anode **24** is preferably inclined in a direction longitudinally of the wires **31** with respect to a normal to the axis of the tube so that X-rays will be propagated from the target area **51** to the right in FIG. 1 from the area **51** shown in FIG. 2. A suitable angle of inclination of said intermediate portion relative to the normal referred to has been found to be 7°.

As shown most clearly in FIGS. 1 and 3, the leads **32** for the cathode structure **30** each have their portions adjacent the wires **31** formed into a plurality of parallel elements **54**, **56** and **58** connected by reverse bends. The parallel elements **54** of the two leads which are farthest from the wires **31** are relatively close together. The intermediate parallel elements **56** are farther apart and the parallel elements **58** nearest the wires **31** are still farther apart so as to provide a concave or trough-shaped resultant structure when viewed in end elevation as in FIG. 2. The leads **26** also include end elements **60** extending across the ends of such trough-shaped structure from the ends of the parallel elements **58**. The end elements **60** of each lead terminate in an end portion **62** adjacent but spaced from the reverse bend between the elements **56** and **58** of the other lead **32**. Such end portion of each lead extends generally normal to the parallel elements **56** and **58** of the other lead and in a direction toward the cathode end of the tube. The end elements **60** are curved so that their central portions are at a greater distance from the intermediate portion **50** of the anode than their end portions. The small diameter wires **31** forming the electron emitting portion of the cathode structure **30** extend between the end elements **60** and are secured by spot welding to the surfaces of such end elements which are remote from the intermediate portion **50** of the anode structure.

It will be apparent that heating current flowing through the leads **32** will flow in parallel through the wires **31**. The wires **31** and leads **32** are preferably made of tungsten and in operation of the tube, such wires are heated by a heating current for a short period of time to a temperature of the order of 2900 to 3000° K. The leads **32** are also heated by such current, such that the elements **54**, **56**, **58** and **60** of the leads reach a temperature of the order of 1900 to 2000° K. This causes impurities to be evaporated from the surfaces of such leads as well as from the wires **31** and also causes a smoothing action due to migration of atoms on the heated surfaces. It is apparent that lower work function materials such as thoriated tungsten may be employed for the wires **31** in which case the operating temperature of such wires can be lowered and the relative size of such wires and the leads can be adjusted to still produce a self-cleaning and smoothing temperature of the leads. Also while a plurality of filament wires are shown in the cathode structure disclosed, it is apparent that a single filament wire can be employed between a pair of leads.

When a high voltage is impressed between the anode **24** and the cathode structure **60** so that the anode becomes highly positive relative to the cathode structure, streams of electrons resulting from both thermal emission and field emission flow from the wires **31** to the anode **24**. The elements **54**, **56**, **58**, **60** and **62** of the leads act as a focusing structure to cause substantially all of such electrons to strike the areas **51** of the anode **24**.

The heating current for the cathode structure is supplied to the leads **32** through the larger leads **34** which extend through the seal **35** and into a recess **64** provided by the reentrant seal structure **36**. The leads **34** are connected in such recess to connector pins **66** held in position in spaced relation to each other by a spacer element **68** of insulating material and by having their head portions imbedded in a body **70** of insulating material cast in situ in and filling the recess **64**. One of the pins **66** also can be employed to provide a cathode connection for applying voltage pulses between the anode structure **22** and the cathode structure **30**. The element **72** may be a plastic or glass cover for the vacuum seal off tube shown in dotted lines at **74** in FIG. 1.

The leads **26** for the anode structure **22** extend through the press seal **27** into a recess **76** provided by the reentrant seal structure **28** at the anode end of the tube. As shown most clearly in FIG. 10, the exterior ends of leads **26** extend through spaced apertures in a small metal terminal block **78** and are held therein by set screws **80**. A third lead **81** extends through the seal **27** between the leads **26** and has its end extending through an aperture in another small metal terminal block **82**. Such end is held in the aperture in the block **82** by a set screw **84**. The two blocks **78** and **82** are insulated from each other by a small strip **86** of insulating material. The recess **76** is otherwise filled with a body of insulating material **88** except for an axially extending cylindrical socket **90** formed in the resin. The socket **90** extends from the exterior surface of the insulating body **88** to the blocks **78** and **82** so that surfaces of such blocks form the bottom surface of such socket. The blocks are otherwise imbedded in the body of insulating material, which material may be case in situ in the recess **76**.

The socket **90** has a diameter providing a snug sliding fit for the end of the cylindrical solid dielectric **92** of a conventional coaxial cable from which the outer tubular conductor **94** has been removed. The block **78** is provided with a tapered aperture **96** concentric with socket **90** for the reception of a protruding end of the central conductor **98** of the coaxial cable. The body **88** of insulating material is preferably somewhat flexible and may, for example, be an epoxy resin or a silicone resin. The same types of resins may also be employed for the body **70** of insulating material at the cathode end of the tube. The solid dielectric of the coaxial cable is also somewhat flexible and by merely pushing the stripped end of such cable into the socket **90** so as to force the free end of the central conductor **98** into the hole **96** in the block **78**, an anode connection is provided which is not easily displaced and which effectively blocks any external air path for flash overs between the anode and cathode connections.

The other block **82** partly imbedded in the body **88** of insulating material provides a connection for one end of the getter heater **46** when the anode connecting cable is removed. The other end of such heater is connected to an end of the member **44** which in turn is connected to one of the anode leads **26** so that heating current may flow through the heater **46** in a gettering operation performed before the tube is put in operation or after operation of the tube to recondition it if gas develops therein.

In operation the tube is positioned in a suitable support. A low voltage, for example, 6.3 volts is impressed across the cathode connection pins **66** to produce a heating current through the electron emitting filament wires **31** and the supporting leads **32** therefor. Such voltage is maintained for approximately 3 seconds and the wire sizes are such that the wires **31** are heated to 2900 to 3000° K. and leads **32** adjacent the wires **31** to 1900 to 2000° K. This means that the leads should have several times the cross-sectional area of the total cross-sectional areas of the filament wires, if made of the same metal as the filament wires. It will be apparent that the relative areas will vary if different metals are employed for the leads and filament wires. As a specific example, five tungsten filament wires **31** each 10 mils in diameter and approximately 1¼-inches long can be employed. The leads **26** may also be of tungsten and have a diameter of approximately 60 mils. At the end of a three second heating period a square wave pulse of voltage, for example, a 300 kv. pulse having a length of 0.2 microsecond, is impressed across the anode and cathode connections of the tube to produce a current through the tube of approximately 1000 amperes. Such voltage is sufficiently high that a large portion of the electron emission from the small diameter filament wires **31** is field emission and an intense beam of electrons emitted from such wires is focused on the target area **50** of the anode by the cathode structure to produce an intense source of X-rays for a very short time. Higher voltage shorter time pulses can be employed and it is apparent that lower voltage pulses of the same or greater time periods may be employed. If a tube has been out of operation for a period of several days, two or more operations of the tube at lower voltages are advisable to condition the tube for higher voltage operations.

The voltage pulses discussed above can be produced, for example, by the discharge of electrical energy stored in banks of transmission lines, such as lumped constant lines or coaxial cables by charging such lines from high voltage sources.

A modified cathode structure **100** is shown in FIGS. 5 to 7. Such cathode structure is similar to the cathode structure of FIGS. 1, 2 and 3, in that a plurality of wires **31** of small diameter extend between end elements **102** forming part of the supporting leads **104** for the cathode. The two leads **104** also have reverse bends to provide parallel side elements **106**, **108** and **110** forming part of a focusing structure. The leads **104** terminate in end portions **112** bent to form a rectangular end structure with the end element **102**. The side elements **106**, **108** and **110** and end elements **102** in conjunction with the end portions **112** form a hollow rectangular structure in which is positioned a focusing element **114** having a surface directed toward the anode of the tube, such as an anode **24** of FIG. 4. The focusing element **114** may be supported on a separate lead **116** passing through a press seal **118** for the leads **104**. In operation the lead **116** will be connected to one of the leads **104** through an external connection. It is apparent that the cathode structure **100** of FIGS. 5 to 7 may be substituted for the cathode structure **22** in a tube otherwise similar to that shown in FIG. 1.

A modified anode structure **120** is shown in FIG. 8 and FIG. 8*a* as including an anode **122** of thin metal foil such as tungsten foil .001 to .002 mil thick. Such foil is formed into an elongated semicircular trough-shaped anode element and is supported at its longitudinal edges by spring clips **124** of thin sheet metal in turn supported on the ends of anode leads **126**, which ends are bent to properly position the anode relative to the cathode structure of the tube. The edges of the foil anode **122** are each folded and engaged in a double fold along one longitudinal edge of one of the clips **124**. Such clips also have cylindrical portions along their outer longitudinal edges fitting the ends of the leads **126**. The joint structure just described provides effective support on and electrical connection of the anode **122** to the leads **126** under widely different temperature conditions even though the spring clips **124** are of a different metal than the anode **122** or leads 126 so as to have a different temperature coefficient of expansion.

The anode structure 122 of FIGS. 8 and 8*a* may be substituted for the anode structure 22 of FIGS. 1, 2 and 4, in tubes otherwise similar to those above described so as to be employed with the cathode structures 30 or 100, also described above. The thin anode 122 provides for X-ray emission from the surface of such anode which is remote from the cathode structure and also enables the anode to be heated by heating current supplied through the leads 126 during out gassing of the tube elements.

The tubes of the present invention are particularly adapted for high speed X-ray work where it is desired to take X-ray photographs of rapidly moving objects, but can also be employed for various other types of X-ray work.

We claim:

1. An X-ray tube comprising an evacuated envelope, an anode supported in said envelope and having an anode electrical connection extending to the exterior of said envelope, a cathode structure including a pair of spaced leads supported in said envelope and having electrical connections extending to the exterior of said envelope in spaced relation to said anode connection, said leads each providing a cathode support portion adjacent said anode, said support portions being spaced from each other and from said anode, and a filament wire secured to and extending in a substantially straight line between said support portions, said leads and filament wire being proportioned to provide for heating said leads adjacent said anode including said support portions to a surface cleaning and smoothing temperature below a thermal electron emission temperature when a heating current is passed in series through said leads and filament wire in an amount heating said filament wires to a thermal electron emission temperature.

2. An X-ray tube comprising an evacuated envelope, an anode and a cathode structure supported in said envelope, said cathode structure including a pair of spaced leads each providing a cathode support portion adjacent said anode, said support portions being spaced from each other, and a filament wire secured to and extending in a substantially straight line between said support portions, said leads and filament wire being proportioned to provide for heating said leads adjacent said anode including said support portions to a surface cleaning and smoothing temperature below a thermal electron emission temperature when a heating current is passed in series through said leads and filament wire in an amount heating said filament wires to a thermal electron emission temperature.

3. An X-ray tube comprising an evacuated envelope, an anode and a cathode structure supported in said envelope, said cathode structure including a pair of spaced leads, said leads each providing a cathode support portion adjacent said anode, said support portions being spaced from each other, and a plurality of spaced substantially parallel filament wires secured to and extending between said support portions to provide a cathode portion of said structure, said leads each having a part extending generally parallel to said filament wires adjacent a side of said cathode portion to provide focusing portions adjacent said anode for electron beams from said wires, said leads and filament wires being proportioned to provide for heating said leads adjacent said cathode portion including said support portions to a surface cleaning and smoothing temperature below a thermal electron emission temperature when a heating current is passed in series through said leads and filament wires in an amount heating said filament wires to a thermal electron emission temperature.

4. An X-ray tube comprising an evacuated envelope, an anode supported in said envelope and having an anode electrical connection extending to the exterior of said envelope, a cathode structure including a pair of spaced leads supported in said envelope and having electrical

connections extending to the exterior of said envelope in spaced relation to said anode connection, said leads each providing a cathode support portion adjacent said anode, said support portions being spaced from each other and from said anode, and a plurality of spaced filament wires secured to and extending between said support portion to provide a cathode portion, said leads each having a part extending generally parallel to said filament wires adjacent a side of said cathode portion to provide focusing portions adjacent said anode to direct electrons emitted from said wires toward said anode when a voltage pulse is impressed between said anode and said cathode structure, said leads and filament wires being proportioned to provide for heating said leads adjacent said anode including said support and focusing portions to a surface cleaning and smoothing temperature below a thermal electron emission temperature when a heating current is passed through said leads and filament wires in an amount heating said filament wires to a thermal electron emission temperature.

5. An X-ray tube comprising an evacuated envelope, an anode supported in said envelope and having a target area and an anode electrical connection extending to the exterior of said envelope, a cathode structure including a pair of spaced leads supported in said envelope and having electrical connections extending to the exterior of said envelope in spaced relation to said anode connection, said leads providing spaced cathode support portions adjacent said anode and extending generally parallel to each other and to said target area, and a plurality of spaced filament wires secured to and extending between said support portions to provide a cathode portion, said leads each having parts extending generally parallel to said filament wires adjacent a side of said cathode portion to provide focusing portions to direct electrons emitted from said wires against said target area when a voltage pulse is impressed between said anode and said cathode structure.

6. An X-ray tube comprising an evacuated envelope, an anode supported in said envelope and having a target area and an anode electrical connection extending to the exterior of said envelope, a cathode structure including a pair of spaced leads supported in said envelope and having electrical connections extending to the exterior of said envelope in spaced relation to said anode connection, said leads providing spaced cathode support portions adjacent said anode and extending generally parallel to each other and to said target area, and a plurality of spaced filament wires secured to nd extending between said support portions to provide a cathode portion, said leads each having a plurality of parts connected to each other by reverse bends and extending generally parallel to said filament wires adjacent a side of said cathode portion to provide focusing portions to direct electrons emitted from said wires against said target area when a voltage pulse is impressed between said anode and said cathode structure.

7. An X-ray tube comprising an evacuated envelope, an anode supported in said envelope and having a target area and an anode electrical connection extending to the exterior of said envelope, a cathode structure including a pair of spaced leads supported in said envelope and having electrical connections extending to the exterior of said envelope in spaced relation to said anode connection, said leads providing spaced cathode support portions adjacent said anode and extending generally parallel to each other and to said target area, a plurality of spaced filament wires secured to and extending between said support portions to provide a cathode portion, said leads each having a plurality of parts connected to each other by reverse bends and extending generally parallel to said filament wires adjacent a side of said cathode portion to provide focusing portions to direct electrons emitted from said wires against said target area when a voltage pulse is impressed between said anode and said cathode structure, said wires and said leads including said focusing portions

and said support portions providing a hollow structure, and a focusing element positioned within said hollow structure and having a surface directed toward said wires to assist in directing said electrons.

8. An X-ray tube comprising an evacuated envelope, an anode and a cathode structure supported in said envelope, said cathode structure including a pair of spaced leads providing spaced cathode support portions adjacent said anode and extending generally parallel to each other, and a plurality of spaced filament wires secured to and extending between said support portions to provide a cathode portion, said leads each having parts extending generally parallel to said filament wires adjacent a side of said cathode portion and intermediate said support portions to provide focusing portions for electrons emitted from said wires.

9. An X-ray tube comprising an evacuated envelope, an anode and a cathode structure supported in said envelope, said cathode structure including a pair of spaced leads providing spaced cathode support portions adjacent said anode and extending generally parallel to each other, a plurality of spaced filament wires secured to and extending between said support portions to provide a cathode portion, said leads each having parts extending generally parallel to said filament wires adjacent a side of said cathode portion and intermediate said support portions to provide focusing portions for electrons emitted from said wires, said wires and said leads including said focusing portions and said support portions providing a hollow structure, and a focusing element in said hollow structure having a surface directed toward said wires.

10. An X-ray tube comprising an evacuated envelope, an anode structure including a pair of spaced leads supported in said envelope and having electrical connections extending to the exterior of said envelope, a cathode structure supported in said envelope and having electrical connections extending to the exterior of said envelope in spaced relation to said anode connections, said leads providing spaced anode support portions extending generally parallel to each other, said anode being a trough-shaped element of metal foil having folded longitudinal edges adjacent said support portions, spring clips having folded portions engaging said folded edges and portions fitting and supported by said support portions, said anode extending partly around said cathode structure.

11. An X-ray tube comprising an elongated evacuated envelope, an anode supported in said envelope and having an anode electrical connection extending to the exterior of one end of said envelope, a cathode structure supported in said envelope in spaced relation to said anode and having electrical connections extending to the exterior of the other end of said tube, said one end of said envelope having a reentrant portion of insulating material providing a recess, the exterior portion of said anode connection terminating within said recess intermediate the depth of said recess in a terminal portion, a body of insulating material filling said recess around said exterior portion and having a cylindrical socket therein extending axially of said recess from the open end of said recess to said terminal portion for receiving and fitting an insulating sheath of a solid dielectric coaxial cable from which the outer tubular conductor of said cable has been removed to thereby provide for engagement of the inner conductor of said cable with said terminal portion and for blocking air paths for electrical flash overs around said tube.

12. An X-ray tube comprising an evacuated envelope and electrical connection structure for said tube, said structure including a reentrant portion of insulating material forming part of said envelope providing a recess, an electrical connection extending through said envelope and having an exterior portion terminating within said recess in a terminal portion intermediate the depth of said recess, a body of insulating material filling said recess around said exterior portion and having a cylindrical socket therein extending axially of said recess from the open end of said recess to said terminal portion for receiving and fitting an insulating sheath of a solid dielectric coaxial cable from which the outer tubular conductor of said cable has been removed to thereby provide for engagement of the inner conductor of said cable with said terminal portion and for blocking air paths for electrical flash overs around said tube.

13. An X-ray tube comprising an evacuated envelope, an anode supported in said envelope and providing an electron receiving surface and having an electrical connection extending to the exterior of said envelope, a cathode structure including a pair of spaced leads supported in said envelope and having electrical connections extending to the exterior of said envelope, each of said leads having a support portion spaced from and extending generally parallel to said surface, said support portions being generally parallel to and spaced from each other, a plurality of filament wires electrically connected at their ends to said support portions and extending between said portions in substantially straight lines and in generally parallel relationship to each other and to said surface.

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Walter P. Dyke et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 70, for "outer" read -- other --; column 8, line 49, for "nd" read -- and --.

Signed and sealed this 21st day of September 1965.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents