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W. P. DYKE ETAL

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VACUUM ARC X-RAY TUBE

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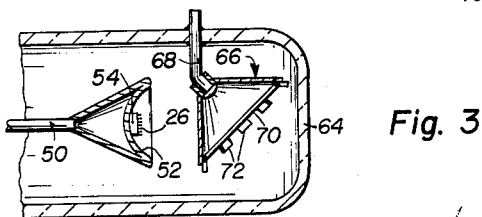
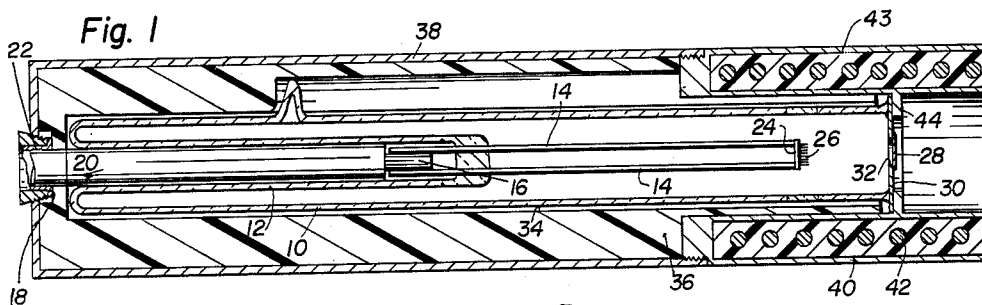


Fig. 2

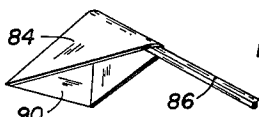
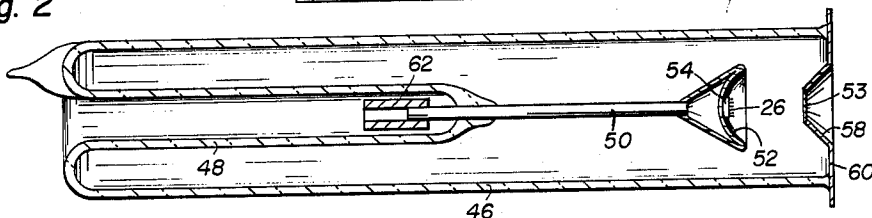


Fig. 5

Fig. 4

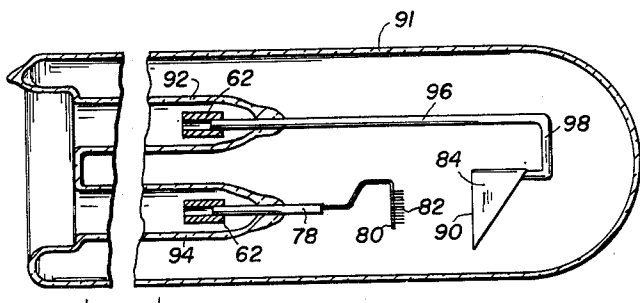
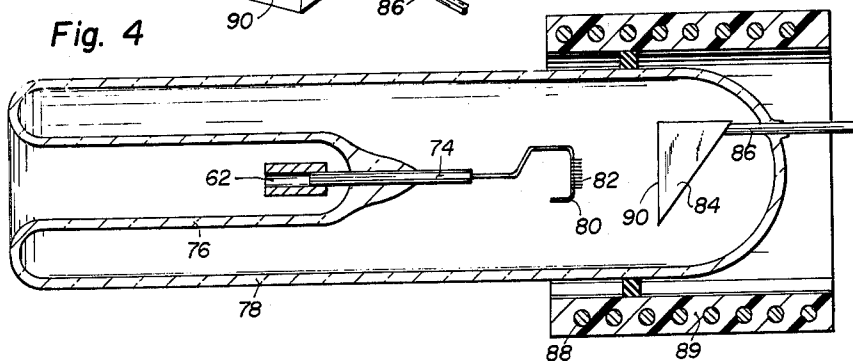


Fig. 6

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VACUUM ARC X-RAY TUBE

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12 Claims. (Cl. 313-57)

This invention relates to a vacuum arc X-ray tube and more particularly to an X-ray tube having an anode of thin sheet metal positioned so that it is struck by rapidly moving electrons emitted from a cathode as the result of a high intensity vacuum arc electric discharge between the cathode and anode, such electrons being focused upon a restricted area of one surface of the anode so that they puncture the anode and produce a pulse of high intensity X-ray radiation from the side of such anode remote from the cathode.

The X-ray tubes of the present invention employ a cathode having at least one sharp needle point spaced from and directed toward a surface of a thin sheet metal anode. In operation a high current, high voltage, pulse of electrical energy is impressed across the gap between the anode and cathode to produce a high intensity vacuum arc electrical discharge of short duration. During such discharge, electrons emitted from the cathode point or points strike the anode at very high velocity. They are focused upon a restricted area of the anode by either electrostatic or electromagnetic focusing and penetrate and puncture the anode. As a result an intense pulse of X-ray radiation is produced from the side of the anode opposite the cathode. Since such radiation is from a restricted area, for example one having a diameter of the order of 1 mm., high resolution is obtained producing very sharp radiographs. The anode is sufficiently thick that substantially all of the electrons have a single collision with an atom in the metal but such anode is also sufficiently thin that few, if any, electrons have multiple collisions so that a narrow range of X-ray spectrum is produced. Under these conditions the focusing of the rapidly traveling electrons upon a restricted area causes a hole of approximately the size of such restricted area to be produced in the anode so that such area of the anode is destroyed. Certain of the tubes in accordance with the present invention are rendered inoperative as a result of one operation of the tube although in other tubes the area of the anode upon which the electrons are focused may be shifted for successive operations so that such tubes are capable of a plurality of operations.

Vacuum arc X-ray tubes employing a supplemental or starting anode in addition to a main anode have been suggested. Initial ionization is produced in such tubes by a spark or arc in a short gap between the starting anode and the cathode. Current flow across such gap is limited by a high resistance in series with the starting anode. The initial ionization enables an arc to be established across a much longer gap between the main anode and the cathode. In such tubes the anodes were thick structures and the useful X-ray radiation was from the surface directed toward the cathode. The area struck by the electrons has been of the order of 1 cm. in diameter. Such tubes did not produce the high intensity nor the high resolution of the present tubes and were erratic in operation so that accurately timed pulses were not obtained. Even though relatively massive electrodes were used the tubes had a short useful life. Furthermore, the manner of initiating the discharge and the large size electrodes made the production of extremely narrow pulses with high rise time impossible. For example, the rise time of the current pulses were of the order of several microseconds, whereas the present tubes can be

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constructed with small electrodes having low inductance and capacitance so that accurately formed X-ray pulses having a pulse width extending into the nanosecond range (10^{-9} seconds) including the rise time can be produced. Also the initiation of the discharge by employing a needle point cathode enables precise timing of such discharge. The sharp needle cathodes increase the electric field for a given voltage so as to cause the arc to be initiated early in the voltage pulse and independently of electrode imperfections or irregularities.

An X-ray tube employing a vacuum arc initiated by a discharge from one or more needle points in conjunction with an anode of sufficient thickness that the anode is not punctured is described and claimed in the copending application of the present applicants, Serial No. 114,125, filed June 1, 1961, now Patent No. 3,174,043. The most intense X-ray radiation is from the surface of the anode directed toward the cathode and which is struck by the rapidly moving electrons. With such tubes the usable X-rays are those emitted at a substantial angle to the normal to the anode surface, which X-rays are less intense than those emitted in a direction substantially normal to such surfaces. Such tubes can be constructed to have long useful lives, for example, many thousands of operations. They produce relatively high intensity and resolution in comparison with the tubes described above employing a starting anode and are capable of producing accurately timed X-ray pulses having pulse lengths of the order of 10^{-8} seconds. In the tubes of the present invention, the most useful X-rays are those emitted from the surface of the anode opposite the cathode in a direction substantially normal to such surface, i.e. in the original direction of travel of the electrons. With the tubes of the present invention, it is possible to produce X-rays having several times the intensity of those produced with the same amount of electrical power by tubes employing an anode which is thick enough to resist puncturing by a high intensity vacuum arc.

The tubes of the present invention require no heater power and may be connected to the power source or pulser through a single transmission line such as a coaxial cable or a cable having two inner conductors of any reasonable length so as to be remotely located. Also the impedances of the power source, cable and tube can be matched to provide for maximum transfer of power with minimum distortion of the pulse shape. Also the tubes can be made small in size so as to be capable of being inserted into openings in objects to be X-rayed such as an opening in a hollow explosive or of being introduced into organs of the body such as the stomach. Such tubes require a minimum of labor and materials and provide improved reliability.

The anode of a tube of the present invention may form a part of the evacuated envelope of the X-ray tube. For example, such anode may be a window of thin sheet metal in an otherwise normally thick walled envelope. The resulting X-ray tube is a destructible or expendable tube, since one operation of the tube renders it inoperative, at least until a new window is applied to the tube and the tube re-evacuated. Such tubes are particularly applicable to being employed in environments in which the tubes are destroyed in any event, for example, in an environment where X-ray photographs of the behavior of a structure during an explosion are being made and the X-ray tubes are destroyed by the explosion. Such tubes produce the highest possible intensity of X-ray radiation, since the X-rays do not have to pass through any layer of solid material before reaching the object to be X-rayed.

Very high intensity X-rays may, however, also be generated in tubes employing a thin sheet metal anode located

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entirely within an evacuated envelope and spaced from a cathode of the type briefly described above. Simple tubes capable of a single operation only and particularly usable in environments where the tube is destroyed can also be provided although it is entirely possible to provide multiple operation tubes by causing the high intensity beam of electrons to strike different areas of the anode in subsequent operations. If magnetic focusing of the electrons upon the anode is employed, the direction of the focusing magnetic field can be varied to focus the electrons on different areas of the anode in successive operations of the tube, or alternatively with either type of focusing the anode can be made movable relative to the cathode and provision made for moving the anode from the exterior of the tube to position different areas of the anode in the path of the rapidly traveling electrons. A considerable number of repeat operations can thus be carried out with a single tube.

It is therefore an object of the present invention to provide an vacuum arc X-ray tube in which a puncturable anode is employed to enable high intensity X-rays to be produced.

Another object of the invention is to provide an X-ray tube in which a high intensity vacuum arc can be produced to cause electrons to travel at high speed from a cathode to an anode of thin sheet metal to thereby puncture such anode and produce a high intensity pulse of X-ray radiation from the surface of the anode which is remote from the cathode.

A further object of the invention is to provide a vacuum arc X-ray tube in which a high intensity pulse of electrical energy is produced between one or more needle points carried by a cathode and a thin sheet metal anode so as to cause electrons to travel at high velocity from the cathode to the anode and in which tube such electrons are focused on a restricted area of the anode so as to puncture the anode and thereby produce high intensity X-ray radiation from the surface of the anode remote from the cathode.

A still further object of the invention is to provide a high intensity vacuum arc X-ray tube for pulse operation in which electrons traveling from a cathode to an anode in a vacuum arc of short duration are focused upon laterally spaced areas of a thin sheet metal anode in successive operations of the tube so that such anode may be punctured during each of such operations but the tube may be employed for repeated operations.

Other objects and advantages of the invention will appear in the following detailed description of various embodiments thereof shown in the attached drawings of which:

FIG. 1 is a longitudinal sectional view of an X-ray tube in accordance with the present invention adapted for magnetic focusing and shown as being mounted in a metallic casing having a magnetic focusing element;

FIG. 2 is a longitudinal sectional view through a modified tube in accordance with the present invention employing electrostatic focusing;

FIG. 3 is a fragmentary view of a further modified tube employing electrostatic focusing and a movable anode;

FIG. 4 is a view similar to FIG. 2 of a modified tube employing electromagnetic focusing and shown in conjunction with a magnetic focusing element;

FIG. 5 is a fragmentary isometric view of the anode of the tube of FIG. 5; and

FIG. 6 is a view similar to FIG. 2, showing a further modified tube having separate reentrant portions extending from the same end of the tube for supporting the cathode and anode.

Referring more particularly to the drawings, the tube of FIG. 1 has an evacuated glass envelope 10 of elongated tubular form. The envelope 10 has a tubular reentrant portion 12 in the inner end of which is sealed a pair of spaced cathode supports 14 which are adapted to make

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contact with a pin 16 attached to the inner conductor of a coaxial cable 18. Such cable has an insulating body 20 from which the outer conductor 22 has been stripped for a portion of its length to enable the insulating body 20 to be inserted within the reentrant portion 12.

A cathode member 24 having a plurality of closely spaced needle points 26 is supported on the ends of the cathode supports 14 so that the needle points 26 are directed axially of the tube toward the surface of an anode 28. The anode 28 is a small circular piece of thin sheet metal brazed, welded or otherwise secured to an annular metal member 30 forming a closure member for the end of the tube opposite the reentrant portion 12. The anode 28 is positioned to close an aperture 32 in such metal member. The metal member 30 may be made of any one of several known alloys which have a thermal coefficient of expansion substantially the same as that of the glass of the envelope 10 in contact with such member. Such annular member 30 is sealed directly to the anode end of the glass envelope 10.

The envelope 10 of the X-ray tube is shown as being mounted in a socket 34 in a cylindrical member 36 of insulating material in turn positioned within a metal casing 38. The external portion of the cylindrical member 36 adjacent the anode end of the tube is cut away to provide room for a magnetic focusing structure including a coil support 40 containing a coil 42 imbedded in insulating material. The coil 42 can be energized by direct current to provide an adjustable focusing electromagnetic field extending axially of the tube. The coil support 40 has a nonmagnetic metal casing member 43 screw-threaded into the anode end of tubular casing 38. The casing member 43 has an internal flange 44 which bears against the annular closure member 30 of the tube in order to hold the tube and the insulating member 36 in the casing 38. The outer conductor 22 of the coaxial cable may be connected to the casing 38 so that such casing and the casing member 43 form a continuation of such outer conductor. It will be apparent that the tube and its mounting shown in FIG. 1 provides a continuation of the coaxial structure of the coaxial cable 18 which will have a characteristic impedance of the same order as that of the coaxial cable.

A high current, high voltage pulse of electrical energy may be delivered to the tube shown in FIG. 1 from an electric pulse generating device of the general type shown in the copending application of Dyke et al., Serial No. 103,796, filed April 18, 1961. Such pulses of electrical energy may, for example, have voltages ranging from 100 kilovolts to 2 megavolts or higher and currents ranging from 1000 to 100,000 amperes or higher, with the length of the pulse varying, for example, from .001 to .5 microsecond. The cathode needle points may have tip curvatures with a radius ranging from 10^{-5} to 10^{-3} centimeters and if a plurality are employed, may be spaced from 1 to 30 mils apart and may project from their supports, for example, a distance of the order of 50 mils. Methods of making and mounting such needle points are discussed in the copending application of Dyke et al., Serial No. 114,125 filed June 1, 1961, now Patent No. 3,174,043. If a single needle point is employed it will, in general, have its end melted and vaporized by the arc and if a plurality of such points are employed on the cathode, usually two or three of such points will have their ends vaporized, in which event, any subsequent discharge in another operation of the tube will, in general, occur from other points. The anode is, in general, made as thin as practicable for mechanical strength reasons and may, for example, be as thin as .0005 inch for the lower voltages mentioned above, while for the higher voltages somewhat thicker anodes up to approximately .01 inch are suitable. The preferred metal for both the anode and the cathode points is tungsten although other metals may be employed, as the nature of the electrode metals is not as critical as is the case with tubes intended for a large

number of successive operations. As stated above, the rapidly traveling electrons can be focused upon a spot on the surface of the anode of relatively small area by means of a magnetic field produced by the coil 42 so that the anode is punctured by such electrons. At the higher voltages the intensity of the X-rays may be, for example, two or three times that obtained with solid nondestructible anodes.

Instead of employing magnetic focusing of the electrons in the vacuum arc, electrostatic focusing can be employed, for example, in a tube structure such as shown in FIG. 2. The tube of FIG. 2 includes an evacuated glass envelope 46 having a reentrant tubular portion 48 in the inner end of which is sealed a cathode support 50. Such support has a metallic focusing cup 52 secured to its exposed end so that the cup is directed axially toward an anode 53 supported at the other end of the tube. A cathode member 54 having a plurality of needle points 26 also directed toward the anode 53 is mounted within the cup 52 so that the electric field between the cathode cup 52 and the anode 53 during the vacuum arc discharge focuses the electrons traveling from the cathode toward the anode onto a relatively small area on a surface of the anode. The anode 53 is a thin sheet metal member secured to and closing an aperture in a conical portion 58 of an annular closure member 60 for the end of the tube. The closure member 60 may be of a suitable metal sealed to the end of the envelope 46 in the same manner that the annular member 30 of the tube of FIG. 1 is sealed to the end of the envelope 10. The cathode support 50 may have a socket member 62 secured to its other end and positioned within the reentrant portion 48. It will be apparent that the tube of FIG. 2 can be mounted in a casing of the general type shown in FIG. 1 and connected to a coaxial cable so as to provide a continuation of the coaxial structure of such cable. The focusing cup 52 takes the place of the focusing coil 42 of FIG. 1 but otherwise the operation of the tube may be similar to that of the tube of FIG. 1.

A modified tube employing electrostatic focusing and having an anode positioned entirely within the envelope 64 of the tube and providing for a limited number of repeated operations of the tube is shown in FIG. 3. Such tube has a cathode cup 52 which may be supported on a support 50. The cup 52 of FIG. 3 may be of the same form as the cup 52 shown in FIG. 2 and may have a cathode member 54 supported therein and provided with needle points 26 directed toward an anode 66. Such anode may be a frusto-conical member of thin sheet metal supported for rotation about its conical axis on an anode support 68 extending laterally through and sealed in a wall of the envelope 64. The large end of the frusto-conical anode member 66 may have a supporting rim 70 of metal wire secured thereto upon which are mounted a plurality of small magnetic elements 72. The anode is positioned so as to have a part of its conical wall aligned with the cathode cup 52 and points 26. It will be apparent that the anode 66 may be rotated by employing a magnet located exteriorly of the envelope 64 so as to selectively position different portions of the anode 66 in position to receive electrons from the cathode 52 as the result of establishing a vacuum arc between the cathode and anode as described above. The X-rays emitted from the anode 66 of FIG. 3 must travel through the glass envelope 64 of the tube and are to some extent thereby diminished, but the intensity of such X-rays are substantially greater than from previously employed thick anodes.

Another modification of a tube in accordance with the invention is shown in FIG. 4 in which a cathode support 74 is sealed in the inner end of a tubular reentrant portion 76 of a tube envelope 78. A cathode 80 in the form of a wire carrying a plurality of closely spaced needle points 82 directed toward a surface of an anode 84 of thin sheet metal is carried by the end of the cathode

support 74. The end of the cathode support 74 within the reentrant portion 76 may be provided with a socket 62 which may be similar to the socket 62 of FIG. 2 for receiving a pin connected to the inner conductor of a coaxial cable.

The anode 84 of the tube of FIG. 4 may be a single piece of thin sheet metal, such as foil, folded into the shape shown in FIGS. 4 and 5 and secured to an anode support 86 in any suitable manner such as by spot welding. The support 86 extends through and is sealed in the end of the envelope 78 opposite the reentrant portion 76. A magnetic focusing structure 88 surrounds the anode end of the tube and has a magnetic coil 89 positioned therein. Direct current flowing through such magnetic coil provides a field extending between the cathode and anode, which can be adjusted to the correct intensity to focus electrons from the cathode points 82 upon a small area on the portion 90 of the anode toward which the points 82 are directed. It will be apparent that the focusing structure 88 may be tipped with respect to the envelope for the tube 78 or alternatively the envelope of the tube may be adjusted through various angles with respect to the focusing structure so that the orientation of the magnetic field with respect to the cathode and the anode can be varied to laterally shift the area upon which the electrons from the cathode are focused during successive operations of the tube. The tube of FIG. 4 can thus be employed for a limited number of repeated operations.

The tube shown in FIG. 6 includes a tube envelope 91 in which two separate reentrant portions 92 and 94 extend from the base of the tube in parallel spaced relationship. One of such reentrant portions 92 has a cathode support 96 sealed in its end. The support 96 has a reverse bend 98 and supports a cathode 84 which may be of the same type as the cathode 84 of FIGS. 4 and 5. An anode support 74 and anode 80 of the same form as the support 74 and anode 80 of FIG. 4 is supported in the reentrant portion 94 and both of the supports 78 and 96 have socket members 62 secured to their ends within the respective reentrant members. The cathode is provided with a plurality of needle points 82 which are directed toward the portion 90 of the anode 84. The tube of FIG. 6 is particularly adapted for connection to the end of a transmission line cable having two inner conductors insulated from each other and from an external shield. The two inner conductors of such cable can each be connected to one of the sockets 62 of FIG. 6 and a casing of the general type shown in FIG. 1 can form a continuation of the external shield of the cable. It will be apparent that the tube of FIG. 6 is adapted for magnetic focusing of the electrons from the cathode 80 on the anode 84.

It will be further apparent that the tubes of the present invention are intended for a single or a limited number of operations and that each operation produces an intense pulse of X-rays from a small area and for a very short period of time. Such operation of X-ray tubes is of importance where it is desired to take X-ray photographs through extremely thick sections without long exposures and particularly where it is desirable to stop rapid motion of elements or parts positioned within other objects having relatively thick wall portions. The tubes which are intended for single operation have particular utility where the tube itself is destroyed, for example, by an explosion, the results of which it is desired to record by an X-ray photograph.

It will be apparent from the above description of the various embodiments of the invention that the details of such embodiments may be varied and that the invention is not limited to such details but that its scope is to be determined by the following claims.

We claim:

1. A vacuum arc X-ray tube, which comprises:
an evacuated envelope,

an anode of thin sheet metal positioned to have at least one surface exposed in the interior of said envelope,

- a cathode having at least one cathode element positioned in said envelope, said cathode element having a sharp field emission portion with a radius of curvature less than 10^{-3} centimeters and being spaced from and directed toward said surface of said anode, and electrical connection means leading to said cathode and anode so that a high voltage, high current, pulse electric discharge can be produced between said cathode and said anode to puncture said anode and simultaneously produce a pulse of high intensity X-ray radiation from the surface of said anode remote from said cathode.
2. A vacuum arc X-ray tube, which comprises:
 an evacuated envelope,
 an anode of thin sheet metal forming a part of the wall of said envelope and having one surface exposed in the interior of said envelope,
 a cathode having at least one cathode element positioned in said envelope, said cathode element having a sharp field emission portion with a radius of curvature less than 10^{-3} centimeters and being spaced from and directed toward said surface of said anode, and electrical connection means leading to said cathode and anode so that a high voltage, high current, pulse electric discharge produced between said cathode and said anode will puncture said anode and simultaneously produce a pulse of high intensity X-ray radiation from the surface of said anode remote from said cathode.
3. A vacuum arc X-ray tube, which comprises:
 an evacuated envelope,
 an anode of thin sheet metal supported within said envelope,
 a cathode having at least one cathode element positioned in said envelope, said cathode element having a sharp field emission portion with a radius of curvature less than 10^{-3} centimeters and being spaced from and directed toward a surface of said anode, and means for connecting said cathode and anode to a source of high voltage, high current pulses capable of producing a vacuum arc between said cathode and anode so that a high voltage, high current, pulse electric discharge produced between said cathode and said anode will puncture said anode and simultaneously produce a pulse of high intensity X-ray radiation from the surface of said anode remote from said cathode.
4. A vacuum arc X-ray tube, which comprises:
 an evacuated envelope,
 an anode of thin sheet metal supported by said envelope and having an electron receiving surface on one side thereof exposed in said envelope,
 a cathode supported by said envelope and having a plurality of spaced needle points in said envelope and directed toward and spaced from said surface, electrical connections leading to said cathode and anode so that a high voltage, high current, pulse electric discharge can be produced between said cathode and said anode, and means for focusing electrons traveling at high velocity from said cathode as a result of said discharge upon a restricted area of said surface so as to cause said electrons to puncture said restricted area of said anode and simultaneously produce an intense pulse of X-ray radiation from the surface of said anode remote from said cathode.
5. A vacuum arc X-ray tube, which comprises:
 an evacuated envelope,
 an anode of thin sheet metal supported by and forming a part of the wall of said envelope and having an electron receiving surface on one side thereof exposed in said envelope,
 a cathode supported by said envelope and having a plurality of spaced needle points in said envelope and directed toward and spaced from said surface,

- electrical connections leading to said cathode and anode so that a high voltage, high current, pulse electric discharge can be produced between said cathode and said anode,
 and means for focusing electrons traveling at high velocity from said cathode as a result of said discharge upon a restricted area of said surface so as to cause said electrons to puncture said restricted area of said anode and simultaneously produce an intense pulse of X-ray radiation from the surface of said anode remote from said cathode.
6. A vacuum arc X-ray tube, which comprises:
 an evacuated envelope,
 an anode of thin sheet metal supported within said envelope and having an electron receiving surface on one side thereof exposed in said envelope,
 a cathode supported by said envelope and having a plurality of spaced needle points in said envelope and directed toward and spaced from said surface, electrical connections leading to said cathode and anode so that a high voltage, high current, pulse electric discharge can be produced between said cathode and said anode, and means for focusing electrons traveling at high velocity from said cathode as a result of said discharge upon a restricted area of said surface so as to cause said electrons to puncture said restricted area of said anode and simultaneously produce an intense pulse of X-ray radiation from the surface of said anode remote from said cathode.
7. A vacuum arc X-ray tube having a puncturable anode, which tube comprises:
 an evacuated envelope,
 an anode of thin sheet metal supported by said envelope and having an electron receiving surface on one side thereof exposed in said envelope,
 a cathode supported in said envelope and having a plurality of spaced needle points directed toward and spaced from said surface, electrical connections leading to said cathode and anode so that a high voltage, high current, pulse electric discharge can be produced between said cathode and said anode, and electrostatic focusing means for focusing electrons traveling at high velocity from said cathode as a result of said discharge upon a restricted area of said surface so as to cause said electrons to puncture said anode and simultaneously produce an intense pulse of X-ray radiation from the surface of said anode remote from said cathode.
8. A vacuum arc X-ray tube having a puncturable anode, which tube comprises:
 an evacuated envelope,
 an anode of thin sheet metal supported by said envelope and having an electron receiving surface on one side thereof exposed in said envelope,
 a cathode supported in said envelope and having a plurality of spaced needle points directed toward and spaced from said surface, electrical connections leading to said cathode and anode so that a high voltage, high current, pulse electric discharge can be produced between said cathode and said anode, and electromagnetic focusing means for focusing electrons traveling at high velocity from said cathode as a result of said discharge upon a restricted area of said surface so as to cause said electrons to puncture said anode and simultaneously produce an intense pulse of X-ray radiation from the surface of said anode remote from said cathode.
9. A vacuum arc X-ray tube having a destructible anode, which comprises:
 an envelope having a vacuum therein,

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an anode of thin sheet metal supported by said envelope and having an electron receiving surface exposed in said envelope,

a cathode supported by said envelope and having at least one needle point in said envelope spaced from and directed toward said surface, 5

means to focus electrons traveling at high velocity from said point upon a restricted area of said surface when a high current, high voltage, electric pulse discharge is produced between said cathode and said anode so that said electrons puncture said anode and a pulse of high intensity X-ray radiation is produced from the surface of said anode opposite said cathode, 10
and means to vary the position of said area on said anode during a subsequent electric pulse discharge to enable a repeated operation of said tube. 15

10. A vacuum arc X-ray tube having a destructible anode, which comprises:

an envelope having a vacuum therein,

an anode of thin sheet metal supported by said envelope and having an electron receiving surface exposed in said envelope, 20

a cathode supported by said envelope and having at least one needle point in said envelope spaced from and directed toward said surface, 25

means to focus electrons traveling at high velocity from said point upon a restricted area of said surface when a high current, high voltage, electric pulse discharge is produced between said cathode and said anode so that said electrons puncture said anode and a pulse of high intensity x-ray radiation is produced from the surface of said anode opposite said cathode, 30

and means to vary the position of said area on said anode during a subsequent electric pulse discharge to enable a repeated operation of said tube, 35
including a support for said anode providing for changing the position of said anode in said envelope relative to said cathode.

11. A vacuum arc X-ray tube having a destructible anode, which comprises:

an envelope having a vacuum therein,

an anode of thin sheet metal supported by said envelope and having an electron receiving surface exposed in said envelope,

a cathode supported by said envelope and having a plurality of closely spaced needle points in said en- 45

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velope spaced from and directed toward said surface, means to focus electrons traveling at high velocity from said point upon a restricted area of said surface when a high current, high voltage, electric pulse discharge is produced between said cathode and said anode so that said electrons puncture said anode and a pulse of high intensity X-ray radiation is produced from the surface of said anode opposite from said cathode, and means to vary the position of said area on said anode during a subsequent electric pulse discharge to enable repeated operation of said tube.

12. A vacuum arc X-ray tube having a destructible anode, which comprises:

an envelope having a vacuum therein,

an anode of thin sheet metal supported by said envelope and having an electron receiving surface exposed in said envelope,

a cathode supported by said envelope and having at least one needle point in said envelope spaced from and directed toward said surface,

magnetic focusing means for producing a magnetic field to focus electrons from said point upon a restricted area of said surface when a high current, high voltage electric pulse discharge is produced between said cathode and said anode so that said electrons puncture said anode and a pulse of high intensity X-ray radiation is produced from the surface of said anode opposite said cathode,

and means to vary the direction of said field relative to said anode to vary the position of said area on said anode during a subsequent electric pulse discharge to enable repeated operation of said tube.

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