Sept. 14, 1943. Z. J. ATLEE 2,329,317

METHOD OF CONDITIONING ANODES

Filed March 19, 1941

Fig. 1.

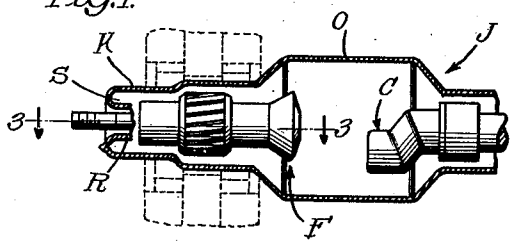


Fig. 2.

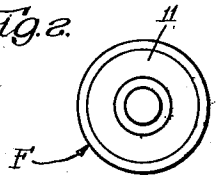


Fig. 3

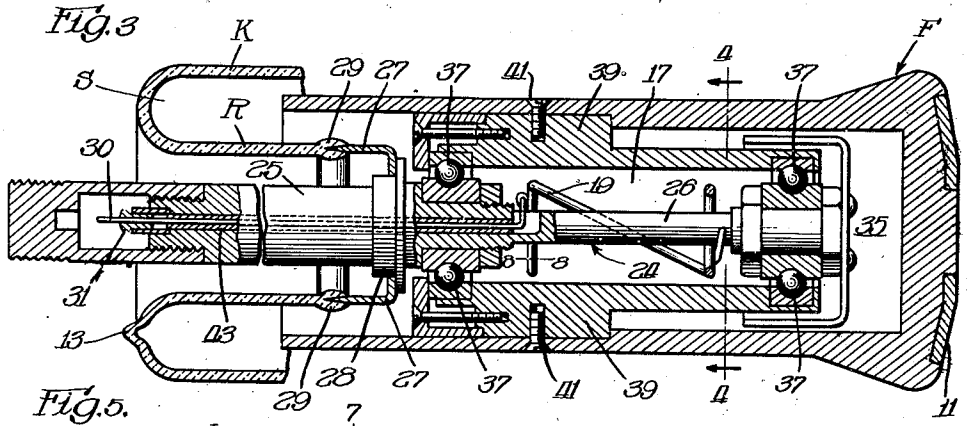


Fig. 5.

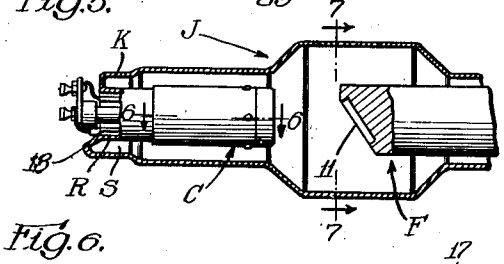


Fig. 4.

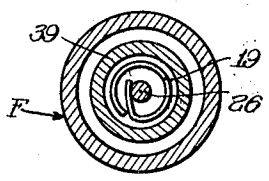


Fig. 6.

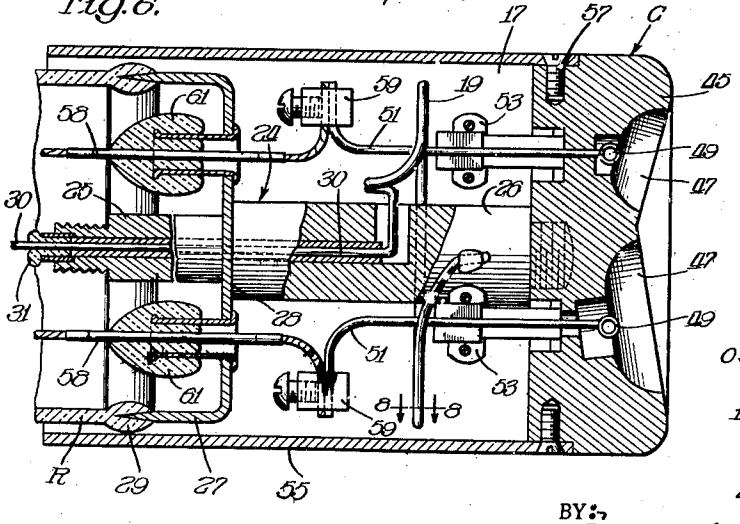


Fig. 8.

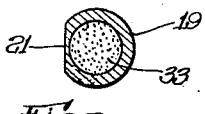
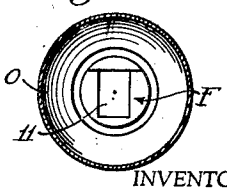


Fig. 7.



INVENTOR.
Zed. J. Atlee

BY:
Spencer, Marzall, Johnston & Cook
Attys.

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2,329,317

METHOD OF CONDITIONING ANODES

Zed J. Atlee, Elmhurst, Ill., assignor to General Electric X-Ray Corporation, Chicago, Ill., a corporation of New York

Application March 19, 1941, Serial No. 384,153

26 Claims. (Cl. 250—27.5)

This invention relates in general to electronics and has more particular reference to X-ray generators, the invention pertaining especially to the conditioning of X-ray generators for use.

An important object of the invention is to provide an improved method of producing X-ray generators in condition for service by submitting the generator to aging and conditioning processes during the fabrication of the same, in order that the finished product may have desired operating characteristics, including the ability to resist deterioration when in operation under high load conditions.

Another important object is to provide an improved technique for aging an X-ray generator, to the end that the parts thereof, and especially the anode, may be conditioned to resist deterioration, particularly through the development of cracks therein when exposed to high temperature encountered in the operation of the generator.

Another important object is to provide an aging technique for anodes, in order to improve the grain structure of the constituent anode material so that the same may be rendered highly resistant to cracking under the destructive forces applied thereto when in service as a part of a finished X-ray generator.

Another important object is to provide an X-ray generator embodying an anode and to condition the anode during the construction of the generator by successively polishing the anode prior to the assembly thereof in the generator, aging the polished anode and the generator by exposing it, after assembly in the generator, to a succession of electrical loads of progressively increasing intensity as a part of a process for conditioning the generator for service; a further object being to age the anode during the evacuation of the generator, thereby conserving manufacturing time, and to provide gettering means adapted to function during the aging operation in order to aid in the final evacuation of the generator; a still further object being to evaporate a gettering medium in the envelope of the generator during the evacuation thereof, and to utilize a metallic bearing lubricant as the gettering means in a generator embodying a rotating anode, an object of the invention being to employ a common evaporable medium for lubricating the bearings of the rotating anode and to accomplish gettering.

Another important object of the invention is to provide an improved anode, particularly for X-ray generators, by subjecting the anode, and especially the target thereof, to electrolysis to polish the same in order to inhibit cracking; a further object being to provide an anode having improved grain structure derived by aging the anode prior to placing it in service; a still further object being to age the anode after the same has been polished.

Another important object is to provide a conditioning technique for anodes, embodying the step of polishing the same, preferably by electrolytic action, in order to reduce cracking of the anode in service.

Another important object is to provide an improved anode conditioning method, embodying a polishing operation to inhibit cracking of the anode in service, and an aging step to improve the grain structure of the anode material to further reduce cracking tendencies.

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

Referring to the drawing:

Figure 1 is a sectional view through an X-ray generator embodying a rotating anode;

Figure 2 is a plan view of the end of the anode of the generator shown in Figure 1;

Figure 3 is an enlarged sectional view taken substantially along the line 3—3 in Figure 1;

Figure 4 is a sectional view taken substantially along the line 4—4 in Figure 3;

Figure 5 is a sectional view through an X-ray generator embodying a stationary anode;

Figure 6 is a sectional view taken substantially along the line 6—6 in Figure 5;

Figure 7 is a sectional view taken substantially along the line 7—7 in Figure 5; and

Figure 8 is a sectional view taken substantially along the line 8—8 in Figures 3 and 6.

To illustrate the invention, the drawing shows X-ray generator means J, comprising an anode F and a co-operating cathode C supported within

a sealed and evacuated envelope O, the invention being illustrated in Figures 1–4, as applied in a generator embodying a rotating anode, and in Figures 5–7, as applied in a generator embodying a stationary anode.

The anode F and cathode C comprise electrodes supported on and in the envelope O, which is formed with cylindrical envelope end portions K for receiving the electrodes at the opposite ends of the envelope, each extension having a re-entrant sleeve-like portion R forming an annular space S between the extension K and the re-entrant portion R, the electrodes being mechanically secured to said re-entrant portions.

The invention has great value in providing X-ray generators having unusually fine operating characteristics at high temperature under relatively heavy load, and results in the ability to produce unusual X-ray intensity from a generator of relatively small size without destructive effect in the generator.

It should be understood that X-ray generators function to produce X-rays in response to the activation of the anode by electronic action produced by the operation of the cathode C. This electronic action comprises the impingement of electrons emitted by the cathode upon a target 11 forming a part of the anode, such electronic impingement resulting in the generation of relatively large quantities of heat, which is dissipated thence through the body of the anode and outwardly of the envelope through the anode support structure, which extends through a sealed opening in the envelope walls. When in operation, the temperature of the generator, and particularly of the anode, may be of the order of 500° centigrade.

The intensity of X-rays produced is a function of the energy applied to the anode, the greater the energy applied, the more intense is the resulting X-ray production. The more energy, however, that is applied on the anode, the higher is the operating temperature to which the anode is subjected. It is desirable, also, to produce X-rays in a sharply defined beam in order to obtain sharp shadow definition on a film or screen, or in applying the X-rays to a desired spot for therapy purposes. For this reason, it is necessary to accomplish electron impingement on the anode on a small focal spot in the target, since the smaller the spot, the greater is the definition accomplished in the resulting X-ray beam. The maximum amount of energy which may be applied on a focal spot or area, without melting or cracking the same, is dependent primarily upon the target material and its ability to resist cracking under the influence of the temperature developed through electronic impingement at the focal spot, which ordinarily is a relatively small localized area in the target face.

Because of its high melting point, high atomic weight and ease of procurement, tungsten is commonly used as a target material for X-ray tubes, although numerous other materials are available. Of all presently known materials, however, tungsten has the greatest ability to resist cracking under the influence of high temperatures. The production of tubes to meet the demand for high capacity units has resulted in a tendency toward a higher incidence of tube failure due to cracking of the target in service. Material available for use in targets, including tungsten, has a definite crystalline grain structure, and the tendency toward target cracking may be minimized by mechanical working of the target material to provide a fibrous grain structure.

Electronic action on the target, when in service, with incidental localized heating, changes the grain structure of the target material, which eventually becomes a fine crystalline structure, despite pre-treatment of the material by mechanical working. This change in structure, in accordance with my present invention, is accomplished, without cracking the target, by means of an aging process whereby the development of the grain structure is caused to take place slowly. If the crystalline grain structure is thus developed successfully without cracking, then danger of cracking the anode in service is substantially eliminated.

I have discovered that the successful development of a satisfactory grain structure may be accomplished with a greater degree of success by first polishing the target in order to eliminate even small fissures and other irregularities in the surface of the target, for by eliminating such irregularities, I find that I am able to greatly reduce target cracking, apparently because cracks start as a result of surface irregularities in the target, even though such irregularities may be of minute proportions. In any event, I have found that the higher the polish initially given to the target the less is the cracking tendency.

In keeping with these deductions, tubes built in accordance with my present invention are constructed by first finishing the anode F, including its embedded target 11, to final form by a careful machining operation, the anode and target being finished as smoothly as possible by mechanical means. The completed anode is then given a mirror polish by subjecting it to electrolytic action in a suitable bath, and where copper anodes having tungsten targets are concerned, it has been found that optimum chemical concentration for anodic polishing by electrolysis comprises an aqueous solution of sodium hydroxide and sodium carbonate, in the following proportions.

	Grams per liter of water
Sodium hydroxide (NaOH)	10
Sodium carbonate (NA_2CO_3)	15

Sodium carbonate is present primarily as a current carrier and has little, if any, action upon the tungsten target, but its presence in the solution is advisable to reduce heating. Furthermore, by having sodium carbonate present in the solution, the minimum concentration of the sodium hydroxide polishing agent can be used, which, in general, tends to produce the best results. The temperature at which satisfactory polishing is obtained is somewhat critical, and for this reason, it is desirable to maintain the solution at a temperature of between 20° and 30° centigrade. If the temperature of the polishing bath exceeds the stated limit, the action of the polishing medium on the tungsten may be increased to a degree resulting in a tendency to etch the surface of the target when a standard solution and electrical current density are employed.

Polishing is accomplished by passing an electrical current through the anode and the polishing solution in which it is suspended for a predetermined time interval. The current density is critical and should be established according to the standard solution and temperature being used. Optimum results with the solution at the concentration and temperature herein disclosed are accomplished at a current density of approximately 120 amperes per square foot, maintained for a

period of the order of ten minutes until a satisfactory polish is accomplished. It is important that the anode be not immersed in, or in contact with, the solution for more than a few seconds without application of electrical current, since contact with the solution in the absence of an electric current will result in etching of the target.

The copper of the anode has a tendency to oxidize as a result of the electrolytic polishing action. Oxidation of the copper produces a black coating thereon, which may be readily removed by immersing the anode in a 25% hydrochloric acid solution without impairing the polish.

After the anode has been mirror polished as aforesaid, it is assembled and sealed in operative postion in the envelope O, together with the cathode C, and the tube is conditioned for operation by first removing all gas present within the envelope O, and also any gas occluded in the anode and cathode and in the material of the envelope itself. If such occluded gases are not substantially entirely removed, they will gradually be released within the envelope and impair the exhausted condition at which the device is designed to operate.

Removal of gases from the envelope is accomplished by baking or otherwise heat treating the entire device at a temperature short of the softening point of the glass, while the envelope is connected with a suitable exhausting apparatus. Removal of occluded gases may also be accomplished by heating the electrodes to a high temperature, either by electron bombardment or by placing the electrodes in a magnetic field fluctuating at frequencies of the order of radio frequency.

According to the present invention, however, I prefer to heat the electrodes by electron bombardment, and thereby accomplish the aging of the anode as a part of the tube conditioning process, although aging of the anode to develop a satisfactory grain structure therein may be accomplished after occluded gases have been completely exhausted from the envelope and the electrodes. Whether or not accomplished during the removal of occluded gases, the anode aging process consists in applying energy on the anode by electronic bombardment initially under small load, the load being gradually increased until the tube is subjected to loads substantially in excess of its rated capacity. In this manner, the target material is caused to crystallize slowly and the strains induced by the rearrangement of the molecular structure of the material as a result of crystallization is held at a safe minimum whereby cracking is prevented.

The anode preferably is not loaded continuously during the aging process, but the tube is given a rest period after each load application, each loading comprising a predetermined amount of energy applied on the anode during a predetermined time interval. The loadings and times are, of course, determined by the size and capacity of the tube being treated and are proportional to the rated capacity of the tube.

The rating of an X-ray tube is ordinarily determined as a function of the energy required to melt the target material, and, consequently, a tube is rated for operation at voltage and current values sufficient to impress on the anode only a predetermined fraction of the energy required to melt the anode material. Thus, for ten second operation, a tube may be rated to operate at voltage and current sufficient to release energy at the anode equal to 60% of target melting energy, 80% of target melting energy during $\frac{1}{10}$ second operation, and 90% of target melting energy when operated during a $\frac{1}{20}$ second interval.

For practical purposes, the aging process preferably is started with electrical energy applications or load shots of the order of one-half of the rated capacity of the tube; and although the invention is not limited to any particular schedule, the following aging schedule has been found satisfactory for tubes rated for operation at 50 kv. p. and 500 milliamperes for $\frac{1}{10}$ second:

Energy applications or load shots	Kv. p./shot	Milliamps./shot	Application time/shot (seconds)	Rest period between shots (seconds)
1	50	50	20	(1)
12	60	300	2	7.5
20	75	300	1	4.5
35	85	300	½	2.5
60	100	300	⅕	1.5

[1] Short interval.

It will be noted from the foregoing schedule that the aging process consists of a series of energy exposures or shots, the first of which is merely a heat exposure accomplished at low energy for a twenty second period for the purpose of initially warming the anode to a temperature of the order of 100° centigrade in order to render the target material ductile and minimize the danger of starting cracks during the aging process. After the initial warming and before the anode has a chance to cool down, say within a minute or two, the tube is given twelve successive exposures or load shots at 60 kv. p. and 300 milliamperes, each shot lasting two seconds, with a rest period of 7.5 seconds between loadings. Thereafter, the tube is subjected to twenty, one second, exposures at 75 kv. p. and 300 milliamperes, with a 4.5 second rest period between exposures. Then the tube is subjected to thirty-five, half second, exposures at 85 kv. p. and 300 milliamperes, with a 2.5 rest period between exposures, and, finally, to sixty exposures of one-fifth second duration at 100 kv. p. and 300 milliamperes, with rest periods of 1.5 seconds between exposures.

The foregoing aging process is designed to allow the crystalline structure of the target material to grow slowly in order to condition the target for full load operation without destructive cracking. After the aging process has been accomplished, the tube is tested by subjecting it to a series of over-load test exposures, which, for a tube rated at 50 kv. p. and 500 milliamperes for $\frac{1}{10}$ second, may comprise twenty-six exposures of $\frac{1}{10}$ second each at 60 kv. p. and 500 milliamperes, with a forty-two second rest period between exposures, followed by fifty-four test exposures, each of $\frac{1}{10}$ second duration, at 70 kv. p. and 500 milliamperes, with a forty-two second rest period between exposures.

By first giving the anode a mirror polish and then aging the anode, I have been able substantially to eliminate anode cracking.

After all impurities, including occluded gases and other impurities, have been removed from the envelope, the exhaust connection may be sealed off, as at 13, and as a final clean-up step, a suitable gettering material may be volatilized within the envelope in order to form end products of the gettering material and any trace of gas or other impurities that may remain in the envelope, such end products being inert and innocuous and remaining within the envelope during the service life of the tube in the form of a

film-like deposit of the gettering material on such surfaces of the device upon which the volatilized material may condense as a result of the gettering operation.

The gettering operation, of course, is a part of the evacuation and cleaning of the tube and may be performed at the conclusion of the clean-up process either before, during, or after the aging of the anode. Any suitable gettering material may, of course, be employed, and I prefer to use barium and/or magnesium and preferably a mixture of the named metals. In any event, the gettering material has a high melting point and is characterized by a tendency to remain immobilized in the tube after being volatilized and condensed as a film as aforesaid. In electron flow apparatus, and particularly in X-ray generators, it is important that the gettering operation be accomplished in such fashion as to prevent deposit of the gettering material on the outer or active surfaces of the electrodes, and I therefore arrange to perform the gettering operation within the envelope in position eliminating the possibility of the deposit of gettering end products upon the external surfaces of the anode and cathode. To this end, I provide for vaporizing the gettering material within a gettering chamber 17 preferably formed within one of the electrodes, which chamber is in open communication with the interior of the envelope through a restricted channel which opens in a direction facing away from the active surfaces of the anode and cathode, so that volatilization of the gettering material within the confined chamber will exert a gettering effect throughout the envelope, while preventing the escape of vaporized gettering material into the envelope, the end products of the gettering operation being deposited on the internal surfaces defining the gettering chamber.

Gettering is accomplished by means of a tubular wire 19, one side of which is of reduced section, as at 21, the wire being arranged in the form of a loop or loops within the gettering chamber with the portion of reduced thickness facing in the direction in which it is or may be desired to project volatilized gettering material. One end of the wire is electrically connected, as at 23, upon an electrode support 24 comprising a stem having a portion 25 extending outwardly of the envelope and a portion 26 extending within the envelope, the stem being formed with a shoulder 28 to which is sealingly secured a cup-shaped seal member 27, the edges of which form a glass-to-metal seal 29 with the re-entrant envelope portion R. One end of the wire 19 is thus electrically connected with the stem portion 25 extending outwardly of the envelope through the seal 29. The other end of the wire 19 is electrically connected outwardly of the envelope by means of a conductor wire 30 which extends through the envelope seal 27 and through a seal 31 formed in the electrode support 24. By connecting the outwardly extending end of the conductor 30 and the outwardly projecting portions of the stem 25 with an external power source, the wire may be heated to a temperature sufficient to vaporize the gettering material 33 which is disposed within the hollow wire 19. The vapor thus generated will be expelled outwardly through the walls of the hollow wire at the section 21 of reduced thickness. Any trace of gas or other impurities remaining in the envelope after the completion of the exhausting operation will be attracted into the chamber 17 and will combine with the volatilized gettering material and be thus rendered innocuous. The gettering vapors and combined impurities, upon impingement on wall surfaces defining the chamber 17, will adhere thereto and be permanently immobilized as a thin film on such surfaces.

As shown in Figures 1–4, the gettering apparatus and chamber 17 may be formed within the anode F, the anode in the illustrated embodiment being of the rotating type and comprising a cylindrical body having an open end extending in the annular space S in position embracing the re-entrant envelope portion R and the seal 29. The cylindrical anode member, at its closed end, carries the target 11 which, of course, on a rotating anode, is annular. The cylindrical anode has a cavity 35 into which the stem portion 26 of the electrode support extends. The stem portion 26 carries spaced preferably roller bearings 37, the inner races of which are secured on the stem 26 and the outer races of which are secured on a cylindrical anode mount 39 which extends within the cavity 35 and forms the gettering chamber 17. The cylindrical anode member snugly encircles and embraces the anode mount and is secured thereto in any suitable fashion, as by means of holding screws 41. It will be seen that the gettering wire 19 is disposed within the chamber 17 around the stem portion 26, and that the wire 19 is disposed in loops, with the portions 21 of said loops facing toward the bearings 37 at the opposite ends of the gettering chamber. One end of the gettering wire is electrically connected with the stem 26, the other end being connected to the conductor 30 which extends through a duct 43 formed longitudinally in the stem portions 25 and 26, the conductor being electrically insulated from the stem portions in the duct 43 and extending through the seal 31 at the outer end of the stem portion 25.

When the gettering material is vaporized, at least a portion of it will impinge upon the working surfaces of the bearings 37, thereby causing the gettering material to deposit on such bearing surfaces as a thin film which forms a eutectic alloy with the bearing material, which alloy, during the life of the tube, will form a lubricating medium between the working surfaces of the bearings.

As shown in Figures 5, 6 and 7, the gettering apparatus and chamber 17 may be formed within the cathode C, the cathode in the illustrated embodiment comprising a head 45 secured on the inwardly extending portion 26 of the electrode support. The head 45 is formed with electrode cavities 47 in which are disposed cathode filaments 49 which are mounted on stems 51 carried in the insulated support brackets 53. The head 45 carries a cylindrical skirt 55 secured at one end, as by fastening screws 57, to the head and extending with the other end of the skirt in the annular space S in position encircling the re-entrant envelope portion R and the seal 29, and enclosing the gettering chamber 17 within the skirt 55 between the head 45 and the seal member 27.

The filament stems are electrically connected, as by clamp means 59, within the chamber 17 with conductors 58 which extend outwardly of the envelope through seals 61 formed in the seal member 27. The gettering wire 19 is formed in a loop with the portion 21 of restricted thickness preferably facing outwardly toward the inner surfaces of the skirt 55, one end of the wire being electrically connected with the inwardly ex-

tending portion 26 of the electrode support, and the other end being connected with the conductor 30 which is insulated from, and extends in, the duct 43 in the stem portions 25 and 26.

The foregoing arrangement of the gettering equipment within a confined chamber in an electrode effectively prevents the escape of any gettering end products and insures against the formation of deposit upon the active surfaces of the electrodes. All of the metallic vapor produced during the gettering operation impinges upon electrode surfaces within the chamber 17. The vaporized gettering material condenses upon such surfaces immediately upon impinging thereon so that little, if any, vapor may escape from within the electrode during the gettering operation. If any vapor should escape, it must do so through the annular opening around the seal 29 and into the space S remote from the active electrode surfaces, and any vapor thus entering the pocket S will become condensed upon the surfaces thereof, which are relatively cool.

By arranging the gettering material 33 on a conductor and evaporating the same by heating the conductor electrically, I am able to control the amount of gettering vapor produced at any time, and I may provide a suitable excess of gettering material so that after initially conditioning the tube for operation by evaporating only a portion of the gettering material, the remaining unused portion of the gettering material will be retained and may be used later in the event that such use should become necessary, during the service life of the tube, either to recondition the same by evaporating additional quantities of the gettering material to clean up gases produced as a result of the operation of the tube, or to recondition the bearings in a rotating anode device. In this way, I can perform several successive gettering and lubricating operations at intervals during the service life of the tube.

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

The invention is hereby claimed as follows:

1. The method of conditioning the anode of an electron flow device for service which consists in gradually increasing the temperature of the anode from a temperature of the order of 100° centigrade or less to a temperature of the order of 500° centigrade or more during an appreciable time interval of the order of several minutes whereby to promote slow crystal growth in the anode material and thereby inhibit the tendency of the material to crack when heated in service.

2. The method of conditioning the anode of an electron flow device for service which consists in aging the anode by subjecting it at successive intervals to loadings comprising electrical energy shots of progressively increasing intensity.

3. The method of conditioning the anode of an electron flow device for service which consists in aging the anode by subjecting it at intervals during an extended treatment period to successive electrical load shots initially of the order releasing less than one-half anode melting energy in the anode and progressively increasing the intensity of the shots until the same are of the order of intensity in excess of the maximum service loading of the anode.

4. The method of conditioning the anode of an electron flow device for service which consists in subjecting it initially at successive intervals to electrical load shots of the order releasing less than one-half anode melting energy in the anode and thereafter to successive load shots of increased intensity, and finally subjecting the anode to load shots to release energy in the anode in excess of the energy to which it is designed to be subjected in service, whereby to promote slow crystal growth in the anode material to obtain a crystal structure therein adapted to inhibit cracking of the anode when heated in service.

5. The method of conditioning the anode of an electron flow device to inhibit cracking thereof in service which consists in gradually heating the anode to promote slow crystal growth in the anode material by dissipating electrical energy in the anode in the form of energy shots released at intervals during an extended treatment period with corresponding rest periods between shots.

6. The method of conditioning the anode of an electron flow device to inhibit cracking thereof in service which consists in gradually heating the anode to promote slow crystal growth in the anode material by dissipating electrical energy in the anode in the form of energy shots of progressively increasing energy intensity released at intervals during an extended treatment period with corresponding rest periods between shots.

7. The method of conditioning the anode of an electron flow device to inhibit cracking thereof in service which consists in gradually heating the anode to promote slow crystal growth in the anode material by dissipating electrical energy in the anode in the form of energy shots released at intervals during an extended treatment period with corresponding rest periods between shots, and increasing the energy value of the shots at intervals during the treatment period.

8. The method of conditioning the anode of an electron flow device to inhibit cracking thereof in service which consists in gradually heating the anode to promote slow crystal growth in the anode material by dissipating electrical energy in the anode in the form of energy shots released at intervals during an extended treatment period with corresponding rest periods between shots, and decreasing the rest periods between shots as the treatment period progresses.

9. The method of conditioning the anode of an electron flow device to inhibit cracking thereof in service which consists in gradually heating the anode to promote slow crystal growth in the anode material by dissipating electrical energy in the anode in the form of energy shots released at intervals during an extended treatment period with corresponding rest periods between shots, and increasing the energy value of the shots while decreasing the rest period between shots as the treatment period progresses.

10. The method of conditioning the anode of an electron flow device to inhibit cracking thereof in service which consists in gradually heating the anode to promote slow crystal growth in the anode material by dissipating electrical energy in the anode in the form of energy shots released at intervals during an extended treatment period with corresponding rest periods between shots, each rest period being of longer duration than its preceding shot.

11. The method of conditioning the anode of

an electron flow device to inhibit cracking thereof in service which consists in gradually heating the anode to promote slow crystal growth in the anode material by dissipating electrical energy in the anode in the form of energy shots released at intervals during an extended treatment period with corresponding rest periods between shots, each rest period being of longer duration than its preceding shot and having a higher ratio between a rest period and the preceding shot as the energy value of the shots is increased.

12. The method of conditioning the anode of an electron flow device to inhibit cracking thereof, which consists in first polishing the surfaces of the anode to mirror smoothness whereby to eliminate surface irregularities and then progressively increasing the temperature of the anode gradually to promote slow crystal growth in the anode material.

13. The method of conditioning the anode of an electron flow device to inhibit cracking thereof in service which consists in mirror polishing and then aging the anode by subjecting it initially to load shots of electrical energy of the order of one-half anode melting energy, then to load shots of higher energy, and finally applying to the anode load shots of energy intensity in excess of that at which the anode is designed to operate in service.

14. The method of conditioning the anode of an electron flow device to inhibit cracking thereof in service which consists in first electrolytically polishing the anode to eliminate surface irregularities by applying a mirror smooth finish thereto and then aging it by applying electrical energy loads in excess of the energy load at which it is designed to operate in service.

15. The method of conditioning the anode of an electron flow device to inhibit cracking thereof in service which consists initially in exposing the anode to electrolytic action in a polishing bath to apply a mirror smooth finish to the target area thereof and thereafter aging the anode by subjecting it at intervals during an extended treatment period to electrical energy loads of progressively increasing intensity, said loads initially being of the order of less than one-half anode melting energy and increasing up to energy loads in excess of the loading at which the anode is designed to operate in service.

16. The method of conditioning the anode of an electron flow device which consists in applying a mirror polish thereto and then aging the anode by subjecting it to loads of progressively increasing intensity, commencing with loads of the order of less than one-half anode melting energy.

17. The method of conditioning the anode of an X-ray tube to inhibit cracking thereof in service which consists in assembling the anode in operative position in the tube, evacuating the tube to clean up occluded gases while subjecting the anode to an aging process comprising a series of successively applied electrical load shots of progressively increasing intensity applied on the anode, and gettering the tube as the final step in the clean-up process.

18. The method of conditioning the anode of an X-ray tube to inhibit cracking thereof in service which consists in assembling the anode in operative position in the tube, evacuating the tube to clean up occluded gases while subjecting the anode to an aging process comprising a series of successively applied electrical load shots of progressively increasing intensity applied on the anode, and gettering the tube as the final step in the clean-up process by evaporating a metallic gettering material in the tube while preventing the deposit of gettering end products on the active surfaces of the anode.

19. The method of conditioning the anode of an X-ray tube to inhibit cracking, which consists in pre-forming the anode with a mirror polish on the active surfaces of the anode, assembling the anode in operative position in the tube, evacuating the tube to clean up occluded gases while subjecting the anode to an aging process comprising a series of electrical load shots of progressively increasing intensity applied successively at intervals on the anode during an extended treatment period to heat the same gradually to promote slow crystal growth in the anode material, and gettering the tube as the final step in the clean-up process by evaporating a metallic gettering material in the tube while preventing the deposit of gettering end products on the active surfaces of the anode.

20. The method of conditioning the rotating anode of an X-ray tube to condition the same for service which comprises pre-forming the anode with an internal pocket, assembling the anode in operative position in the tube with anode bearings in the pocket, evacuating the tube to clean up occluded gases, rotating the anode and evaporating a metallic medium in the anode pocket while directing the vaporized medium and condensing it upon the anode bearings to form thereon a lubricating alloy, and subjecting the anode to an aging process comprising a series of electrical load shots of progressively increasing intensity applied successively at intervals on the anode during an extended aging period to thereby gradually heat the anode through the dissipation of electrical energy therein, thus raising the anode from a temperature of the order of 100° centigrade or less to a temperature of the order of 500° centigrade or more, in order to promote slow crystal growth in the anode material for the inhibition of anode cracking when heated in service.

21. The method of conditioning the anode of an X-ray tube to inhibit cracking, which consists in pre-forming the anode with an integral pocket and a mirror polish on the active external surfaces of the anode, assembling the anode in operative position in the tube with anode bearings in the pocket, evacuating the tube to clean up occluded gases, rotating the anode and evaporating a metallic medium in the anode pocket while directing the vaporized medium and condensing it upon the anode bearings to form thereon a lubricating alloy, subjecting the active surfaces of the anode to an aging process comprising a series of electrical energy load shots of progressively increasing intensity applied on the anode at intervals during an extended treatment period while the same is rotating, and evaporating the metallic medium in the anode pocket at the conclusion of the clean-up process.

22. The method of conditioning the anode of an electron flow device for service which consists in aging the same by gradually increasing the temperature of the anode from a temperature of the order of one hundred degrees centigrade or less to a temperature of the order of five hundred degrees centigrade or more during an appreciable time interval of the order of several minutes whereby to promote slow crystal growth in the anode material and thereby

inhibit the tendency of the material to crack when heated in service, and finally allowing the anode to cool at a rate such as to preserve the crack resisting crystal structure produced by the aging process.

23. The method of conditioning the anode of an electron flow device for service which consists in aging the same by subjecting it initially, at succesive intervals, to electrical load shots of the order releasing less than one-half anode melting energy in the anode, and thereafter subjecting the anode to successive load shots of increased intensity, and finally subjecting the anode to load shots to release energy in the anode in excess of the energy to which it is designed to be subjected in service whereby to promote slow crystal growth in the anode material to obtain a crystal structure therein adapted to inhibit cracking of the anode when heated in service and then allowing the anode to cool at a rate such as to preserve the crack resisting crystal structure.

24. The method of conditioning the anode of an electron flow device to inhibit cracking thereof in service which consists in aging the same by gradually heating the anode up to a temperature of the order of five hundred degrees centigrade to promote slow crystal growth in the anode material by dissipating electrical energy in the anode in the form of energy shots released at intervals during an extended treatment period with corresponding rest periods between successive shots, and finally allowing the anode to cool at a rate such as to preserve the cracking resisting crystal structure developed in the anode by the aging process.

25. The method of conditioning the anode of an electron flow device to inhibit cracking thereof in service which consists in first polishing the surfaces of the anode to mirror smoothness whereby to eliminate surface irregularities and then aging the anode by progressively increasing the temperature thereof gradually to promote slow crystal growth in the anode material and thereby develop crack resisting crystal structure therein, and finally allowing the anode to cool at a rate such as to preserve the crack resisting crystal structure.

26. The method of conditioning the rotary anode of an X-ray tube for service which consists in pre-forming the anode with an internal pocket and a mirror polish on the active internal surfaces thereof, assembling the anode in operative position in the X-ray tube with anode bearings in the pocket, evacuating the tube to clean up occluded gases, rotating the anode in the tube while evaporating a metallic gettering medium in the anode pocket for preliminary gettering purposes and directing the vaporized medium and condensing the same upon the anode bearings to form thereon a lubricating alloy, subjecting the active polished surfaces of the anode to an aging process comprising a series of electrical energy load shots of progressively increasing intensity applied on the anode at intervals during an extended treatment period, while the anode is rotating, in order to promote slow crystal growth in the anode to develop crack resisting crystal structure therein, evaporating additional quantities of the metallic gettering medium in the anode pocket for final gettering purposes, and then allowing the anode to cool at a rate such as to preserve the crack resisting crystal structure produced by the aging process.

ZED J. ATLEE.