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X-RAY GENERATOR TUBES

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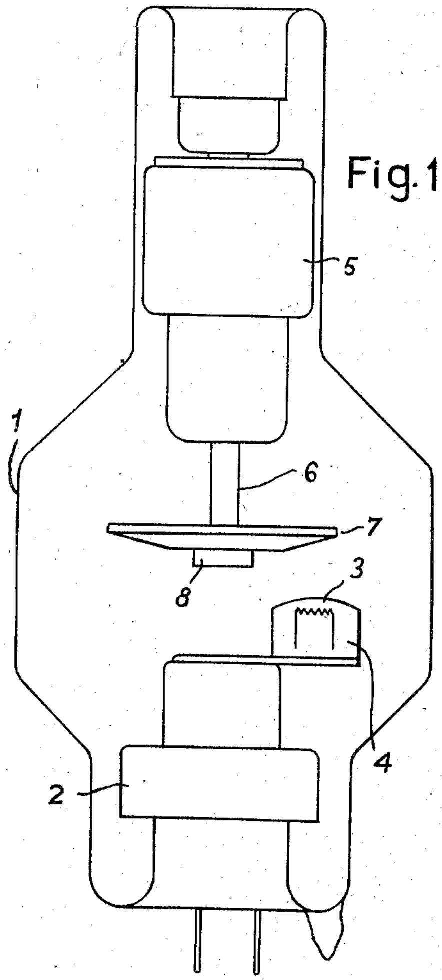
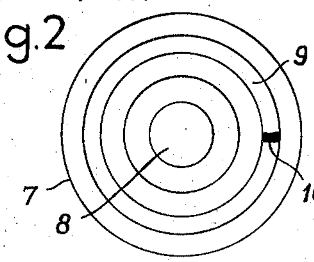


Fig.1

Fig.2



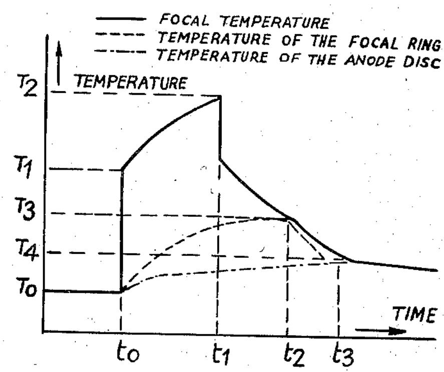


Fig.3

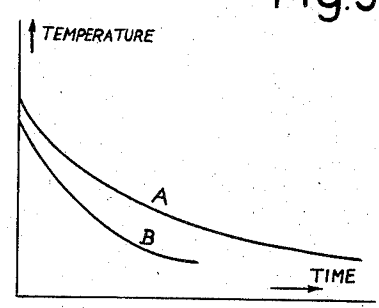


Fig.4

Fig.5

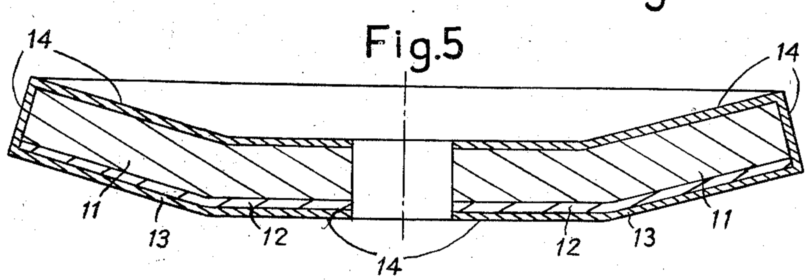


Fig.6

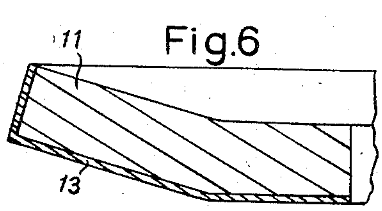
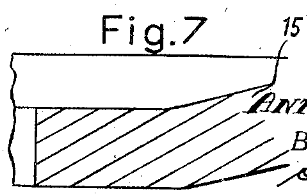


Fig.7



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X-RAY GENERATOR TUBES

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This invention relates to X-ray generator tubes.

In tubes such as X-ray generator tubes, the dissipation of heat from the anode is the principal problem encountered, because almost the whole of the energy of the electron beam is there transformed into heat. In particular, it is the speed of cooling of the anode which limits the rate of making successive exposures, or exposures following viewing. For X-ray generator tubes with a rotatable anode, for example the cooling takes place principally by radiation from the anode.

It is moreover necessary that the anode, at least the part bombarded by the electrons, shall be constituted up to a certain depth (at least 10 microns) of a metal having a high atomic number and which is very refractory. Hitherto generally it is tungsten that is used. Particularly in the case of a rotatable anode, it is desirable that the thermal capacity shall be great, in order to allow the storage of a large quantity of heat before reaching the maximum admissible temperature.

It is therefore an object of the present invention to provide an improved construction of anode for X-ray generator tubes in which the speed of cooling of the anode is considerably increased.

It is a further object of the invention to provide such an anode having an increased thermal capacity.

It is a specific object of the invention to provide an anode for an X-ray generator tube in which at least the part of the anode surface which is bombarded by electrons, consists of the metal rhenium.

It is yet another object of the invention to provide improved X-ray generator tubes incorporating such anodes.

Other objects and advantages of the invention will appear from the following description taken in conjunction with the accompanying drawing, in which:

Figure 1 is a diagrammatic elevational view of an X-ray generator tube having a rotatable anode, which may be formed according to the present invention,

Figure 2 is a plan view of the anode assembly of the tube in Figure 1,

Figures 3 and 4 are explanatory graphs,

Figure 5 is a cross section, on a larger scale, through an anode assembly according to the present invention, intended for the tube shown in Figures 1 and 2, and

Figures 6 and 7 are fragmentary cross-sections of modified constructions of anode assemblies according to this invention.

Referring to Figures 1 and 2, there is shown by way of example, a type of X-ray generator tube having a rotatable anode. The glass envelope of this tube contains, in a very high vacuum, the cathode system **2**, of which the filament or filaments **3** in the concentrating member are located opposite to the conical portion of a disc **7** forming the anode of the tube, which is joined by a rod of molybdenum **6** and a screw **8**, to the rotor **5**. By applying a high tension voltage so that the cathode is negative and the anode is positive, a beam of electrons emitted from the incandescent filament, bombard the focal seat **10** and produce X-radiation at this point. The energy is

transformed almost entirely into heat which, leaving the focal seat **10**, rapidly reaches the focal ring **9** and finally the whole mass of the anode **7**.

The tube structure above described is of a known type and the rate at which successive exposures may be made, or at which exposures may be made following a viewing, depends upon the thermal capacity of, and the speed of cooling from the anode disc **7**.

As shown in the full line curve in the graph of Figure 3, during a radiographic exposure, the focal temperature starts from T_0 rises suddenly to T_1, then during the exposure which lasts from the instant t_0 to t_1, rises from T_1 to T_2. This increase follows that of the focal area or ring **9** which, during the same time, passes from T_0 to T_3, as shown in the broken line curve. Finally, as shown in the chain line curve, the temperature of the anode disc **7** also rises during the exposure and passes from T_0 to T_4; T_4 being lower than T_3.

The ageing of the anode **7** causes a fall of X-radiation depending on the temperature of the focal seat **10**. It is thus plain that it is of interest to start from a temperature T_0 which is as low as possible. Now, it is often necessary to make several exposures very close to each other or an exposure after a viewing. This possibility depends on the speed of cooling of the anode.

For a given anode, cooled principally by thermal radiation, the speed of cooling is proportional to the thermal dissipation which follows the Stephan-Boltzmann law:

$$W = \epsilon \delta S (T^4 - T_0^4)$$

where:

W=the heat radiated in watts
ϵ=the total emissivity of the surface at the temperature T
δ=constant=$5.67.10^{-12} W/cm.^2 K^4$
T=the temperature of the surface in ° K.
T_0=the ambient temperature in ° K.
S=the radiating surface in cm.^{2} (apparent surface)

For the temperatures in question it is possible to neglect T_0^4 compared with T^4. For given T and S, it is then necessary to increase δ if it is desired to improve W. Now, for tungsten ϵ has, more or less, the following values:

At 1000° K	0.114
At 1500° K	0.192
At 1700° K	0.222
At 2000° K	0.260
At 2500° K	0.303

The theoretical maximum $\epsilon=1$ which corresponds to a "black body" which shows that from the point of view of thermal dissipation a tugnsten surface is not ideal.

Methods are known for increasing the actual surface area of an anode, such as sand blasting, chemical attack or electrochemical action, which allows ϵ to be increased to a certain extent.

A certain number of other processes have also been proposed which consist in a deposit of another material, increasing the actual surface and at the same time the intrinsic emissivity. These processes however present serious disadvantages for a tube of which the anode operates at high temperature such as an X-ray generator tube, which is easily understood because the majority of these processes are proposed for electron tubes of which the anode remains at a low temperature. Thus, it has been suggested to deposit refractory carbides directly by electrophoresis, or by depositing a metallic oxide subsequently treated by thermal or chemical methods, or by depositing a mixture of carbides and oxides of metals. The calcining of mixtures of carbides of zirconium and metallic zirconium, or other refractory carbides has also been proposed. Finally, the calcining of a powdered tungsten or another refractory metal has been suggested. When dealing with a deposit by electrophoresis on an anode of an X-ray generator tube, the adherence of the deposit is not always satisfactory, and it is necessary to spare the focal area of the anode so as not to reduce the efficiency of the X-rays and also because most of these deposits do not support very high temperatures. These processes are therefore neither reliable nor economical; it is very difficult to obtain deposits which are regular and only where desired, and without the liberation of a excessive quantity of gas at high temperature. There are classical processes for the carbonisation of nickel anodes, giving a very efficient cooling. But these anodes cannot operate at the temperatures usually met within tubes such as X-ray tubes.

The present invention eliminates these disadvantages by employing the metal rhenium in order to cover the whole surface, or a part of the surface, of the anode. In effect, the thermal emissivity of rhenium is higher than that of tungsten at all temperatures encountered during the operation of the tube. By reason of its atomic number, which is higher than that of tungsten (75 instead of 74) and by reason of its melting point being near to that of tungsten and on account of its very low vapour pressure, the focal surface can also be covered with rhenium.

The present invention also provides X-ray generator tubes with an anode having an increased thermal capacity. In effect, the use of rhenium allows a refractory base to be used with highe thermal capacity than tungsten since one is not confined by the necessity of having a high atomic number. The refractory base may be, for example, molybdenum, graphite or boron. It is sufficient to have on the focal area where the X-rays are produced, a thickness of rhenium sufficient so that all the X-radiation originates from the rhenium. Molybdenum in particular is interesting.

Figure 5 shows diagrammatically, a section through a rotatable anode according to the present invention, which may be incorporated in the tube of Figures 1 and 2. This anode consists of a refractory base structure **11**, of molybdenum which is partially covered with an intermediate layer of a refractory metal **12** such as tungsten, over which is deposited a final outer layer **13**, of rhenium having a thickness of at least 10 microns on the focal ring. The remainder of the surface of the molybdenum can also be covered with rhenium **14** of the same thickness or of less thickness. According to another embodiment of the invention, the non-focal surface **14** is blackened by a known process.

Figure 6 shows a diagrammatic fragmentary section of part of another anode disc, in which the refractory base structure **11**, for example of boron, is covered directly with a layer of rhenium **13** extending over the lower surface of the anode.

Figure 7 shows a diagrammatic fragmentary section of part of another anode structure according to this invention, in which the anode consists simply of a massive disc **15** of rhenium.

By the present invention, it is therefore possible to obtain anode structures having a higher thermal capacity than tungsten anodes, whilst increasing at the same time the amount of X-radiation.

The metal rhenium presents, moreover, physical and mechanical characteristics which are advantageous at high temperatures, and which are used by the present invention. For example, a rotating anode of tungsten and rhenium or of rhenium alone allows operation at a higher temperature than an anode of tungsten.

Figure 4 shows the speed of cooling of a tungsten anode in curve A and of an anode according to the present invention in curve B.

It is possible to choose between several methods of obtaining a layer of rhenium on a refractory base. Preferably an electrolytic method is used. A bath having a base of perrhenate of potassium is very practical:

$KReO_4$	11 g./l.
H_2SO_4 (d=1.84)	pH 0.9
Temperature	20 to 75° C.
Current density	5 to 15 A/dm.^{2}
Anode	Platinum

It is of advantage firstly to deposit a very thin layer of the order of one micron, followed by a flash in hydrogen to 1000° C. Then it is possible to deposit the desired thickness by proceeding with intermediate flashes in hydrogen. The electrolytic process is of very great advantage if it is desired to obtain a layer on one part only of the surface of the refractory base and if it is desired to vary the thickness of the layer from one place to another.

Another recommended process is the deposition in vapour phase, by the decomposition of a halogenide of rhenium, in particular $ReCl_5$, on a base heated to between 500 and 1500° C. in vacuum, or in an inert gas.

Metallisation by spraying and calcining also enables a layer of rhenium to be obtained on a refractory base.

Whilst particular embodiments have been described, it will be understood that various modifications may be made without departing from the scope of this invention. Thus, although particular reference has been made to X-ray generator tubes having a rotatable anode, the invention may equally be employed in such tubes having a non-rotatable anode.

I claim:

1. An anode for an X-ray generator tube, in which at least the part of the anode surface which is adapted to be bombarded with electrons consists of the metal rhenium.

2. An anode for an X-ray generator tube, consisting of a massive disc of the metal rhenium.

3. An anode for an X-ray generator tube, consisting of a core of a refractory material covered with a layer of rhenium over at least a part of its surface and extending over at least the focal area of the anode.

4. An anode as claimed in claim 3, in which the core of refractory material consists of molybdenum.

5. An anode as claimed in claim 3, in which a layer of tungsten is provided on a part of the surface of the core, under the layer of rhenium.

6. An anode for an X-ray generator tube consisting of a core of a refractory material, a layer of tungsten covering at least a part of the surface of the refractory material and a layer of rhenium over said layer of tungsten and covering at least the focal area of the anode, to a depth of at least ten microns.

7. An anode as claimed in claim 6, in which the base of refractory material consists of a metal other than tungsten or rhenium.

8. An X-ray generator tube comprising an envelope containing a cathode assembly, a filament associated with the cathode assembly and an anode spaced from said cathode assembly in which at least the focal area of the anode which is bombarded by electrons to produce the X-radiation consists of the metal rhenium.

9. An X-ray generator tube comprising an envelope containing a cathode assembly, a filament associated with the cathode assembly and an anode spaced from said cathode assembly and made of the metal rhenium.

10. An X-ray generator tube comprising an envelope containing a cathode assembly, a filament associated with the cathode assembly and an anode spaced from said cathode assembly, said anode comprising a core of refractory material, and a layer of rhenium extending over at least the focal area of the core which is bombarded by electrons to produce the X-radiation.

11. A tube as claimed in claim 10, in which the core of refractory material consists of molybdenum.

12. A tube as claimed in claim 10, in which the layer of rhenium is at least ten microns thick over the focal area of the anode.

13. An X-ray generator tube comprising an envelope containing a cathode assembly, a filament associated with the cathode assembly and an anode spaced from said

cathode assembly, said anode consisting of a core of refractory material and a layer of rhenium extending only over the focal area of the core which is bombarded by electrons to produce the X-radiation, said layer of rhenium having a thickness of at least ten microns.

14. A tube as claimed in claim 13, in which the core is made of molybdenum.

15. An X-ray generator tube comprising an envelope containing a cathode assembly, a filament associated with the cathode assembly and an anode spaced from said cathode assembly, said anode consisting of a core of a refractory material, a layer of tungsten covering at least the focal area of the refractory material and a layer of rhenium extending over said layer of tungsten and having a thickness of at least ten microns.

16. An X-ray generator tube comprising an envelope containing a cathode assembly, a filament associated with the cathode assembly and an anode spaced from said cathode assembly, in which at least the focal area of the anode which is bombarded by electrons to produce the X-radiation consists of the metal rhenium, and the remainder of the surface of the anode is blackened.

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