Aug. 18, 1942. Z. J. ATLEE 2,293,037

ANTIFRICTION PROCESS AND PRODUCT

Filed July 13, 1939

FIG. 1.

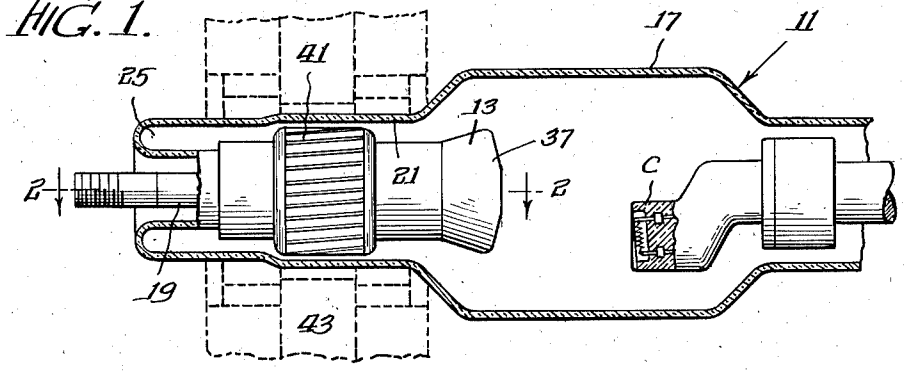


FIG. 2.

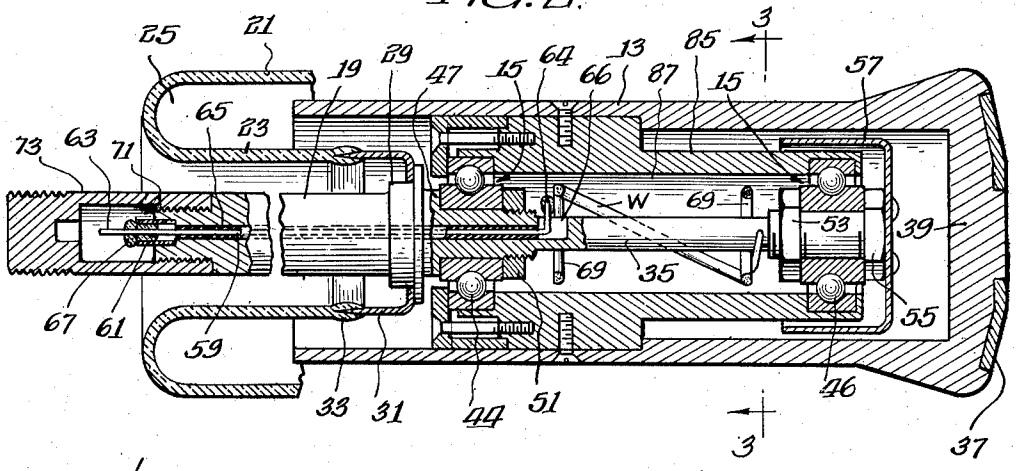


FIG. 3.

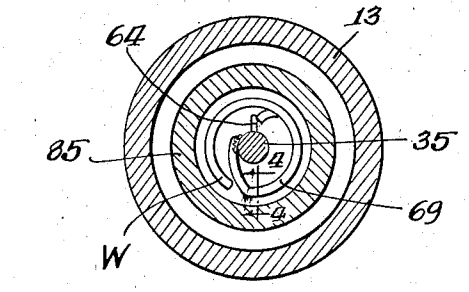
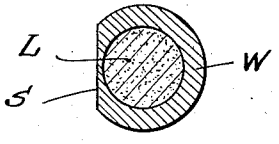


FIG. 4.



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2,293,037

UNITED STATES PATENT OFFICE

2,293,037

ANTIFRICTION PROCESS AND PRODUCT

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Application July 13, 1939, Serial No. 284,273

18 Claims. (Cl. 250—148)

My invention relates in general to anti-friction devices, and has more particular reference to bearings, especially bearings for service under vacuum conditions.

An important object of the invention is to provide a self lubricated bearing employing a lubricant which will not evaporate under low pressure conditions.

Another important object resides in providing a bearing adapted for operation under low pressure or vacuum conditions such as are encountered within the envelopes of X-ray tubes and other evacuated casings, the bearing being capable of retaining its anti-friction qualities without resort to lubrication as presently applied in bearings, a further important object being to process anti-friction devices of the character mentioned by applying to the working surfaces of the device a metallic medium adapted to alloy with the material of the working surfaces and form a thin anti-friction or lubricating film of alloy thereon; a further object being to utilize, as an alloy forming medium, a material such as barium, caesium, strontium, calcium, chromium, copper, silver, aluminum, iron and nickel, having a vapor pressure of the order of 10^{-9} at atmospheric pressure and not to exceed 10^{-6} at high temperatures of the order of 200° centigrade, whereby the lubricating alloy film may not evaporate or otherwise migrate from a treated bearing operating under low pressure and high temperature conditions.

Another important object is to provide an improved bearing particularly for use in X-ray generators to support a rotating element of the generator for operation within a sealed evacuated enclosure in which the operating temperature at the processed bearing may reach the order of 200° centrigrade and up.

Another important object resides in applying an alloy forming medium of the character mentioned by flashing the same as a vapor upon the bearing surfaces to be treated, and causing the vapor to condense upon said surfaces to alloy with the material thereof and form therewith a thin anti-friction alloy film of relatively soft material having lubricating qualities but which will not migrate from the treated surfaces even under conditions of high temperature and low pressure through the mechanical cohesion of the filmed material and its low vapor pressure.

These and numerous other important objects, advantages, and inherent functions of the invention will become apparent as the same 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 taken through an X-ray generator provided with a rotating anode supported by a bearing structure of a type adapted for treatment in accordance with my present invention;

Figure 2 is an enlarged sectional view taken substantially along the line 2—2 in Figure 1, illustrating one mode of applying my present invention;

Figure 3 is a sectional view taken substantially along the line 3—3 in Figure 2; and

Figure 4 is an enlarged sectional view taken substantially along the line 4—4 in Figure 3.

To illustrate my invention I have shown on the drawing an X-ray generator 11 comprising a rotating anode 13 supported within a sealed envelope 17 on bearings 15, although it will be apparent, as the description proceeds, that my invention is not necessarily limited to X-ray generators or even necessarily to bearings for operation under conditions of high temperature and low pressure. Nevertheless, my invention has great value in providing improved bearing means having unusually fine operating characteristics at high temperature and low pressure, and so I have chosen to demonstrate my invention as applied in X-ray generators, in the operation of which such excessive conditions of high heat and low pressure are encountered.

The generator shown, of course, includes a cathode C of any usual or preferred character, and the anode is supported by the bearings 15 on a spindle 19, which is shown mounted on and supported by the envelope 17 at one end thereof. The bearings, of course, may be any suitable or preferred form, but for use in X-ray tubes, I prefer to employ roller bearings comprising balls and races of suitable material, such as steel, as shown in the drawing. As shown, the envelope has an extension 21, within which the anode 13 is snugly disposed for rotation, the envelope having a reentrant sleeve-like portion 23 forming an annular space 25 between the envelope extension 21 and the reentrant portion 23.

The spindle 19 has an outwardly extending portion which is provided with means 29 forming an annular shoulder carrying an annular flanged member 31 sealed thereon. The member 31 has a peripheral edge forming a glass-to-metal seal 33 with the inner end of the reentrant envelope portion 23. This seal, through the member 31,

supports the spindle on the envelope with a spindle portion **35** extending within the envelope, the anode bearings **15** being mounted on said inwardly extending spindle portion **35**.

It should be understood that X-ray generators function to produce X-rays in response to the activation of the anode by electronic action established by the operation of the cathode C. This electronic action comprises the impingement of electrons emitted by the cathode upon a target **37** forming a part of the anode, and such electronic impingement results in the generation of relatively large quantities of heat, which is dissipated thence through the body of the anode **13**, and also into the interior of the casing **17**. When in operation, the temperature of the X-ray generator and particularly of the anode may be of the order of 500° centigrade.

In conditioning an X-ray generator for operation, the envelope **17** is treated to remove all gaseous and other impurities, the same being accomplished by evacuating the envelope as by means of a molecular exhaust pump while heating the elements of the generator to a high temperature in order to drive out gases occluded in the envelope and all of the elements contained therein. The envelope finally is sealed after all impurities have thus been eliminated.

During the operation of the X-ray generator as such, the anode **13** is desirably rotated at high speed, in order to minimize the danger of overheating and burning the target itself, as a result of electron impact. Considerable difficulty has been encountered in providing means for supporting the anode for rotation during the life of the generator, under the excessively high temperature conditions and the low pressure necessarily maintained within the envelope **17**, since it is not feasible to apply usual bearing lubrication because lubricants of the character heretofore known will not remain in the bearings under the low pressure condition necessarily maintained in the envelope, but will instantly evaporate and become dissipated within the envelope, thus not only robbing the bearings of lubricant but also destroying the vacuum in the tube and rendering the same inoperative. Consequently, it has not heretofore been considered feasible to lubricate bearings under conditions necessarily maintained in X-ray generators. Excessive bearing wear results, particularly at the high temperatures encountered in the generator, with the resultant development of anode vibration, which rapidly renders the device unusable. Excessive bearing wear also results in the production of minute wear products, which also impair the operation of the generator as the same become dissipated from the bearings within the envelope.

My present invention relates to a method of lubricating bearings in a manner avoiding the aforesaid difficulties, particularly encountered in X-ray generators having rotating anodes; but the invention is by no means limited to such particular apparatus and, in fact, may be applied to advantage in any bearing structure.

In practicing my invention, I select a suitable material adapted to be applied as a vapor and to condense and form a film upon the bearing surfaces to be treated, the selected material desirably having several qualities, including not only softness and flowability, with low internal coefficient of friction when in film-like form, but also sufficient mechanical cohesion to cause the filmed material to be retained upon the treated bearing surfaces, the property of "wetting" the bearing surfaces to be treated, low vapor pressure to prevent evaporation at the pressures and temperatures to which the treated bearing is to be exposed, and, unless the bearing is to be in operation in an oxygen-free atmosphere, the lubricating material should not normally oxidize. Where the bearing is applied in an evacuated X-ray generator, the problem of oxidation of the filmed lubricating medium will not, of course, be encountered. However, if the treated bearing is for use in the ordinary atmosphere, or elsewhere exposed to oxidation, the lubricating medium should be of a character normally resisting oxidation.

I have found that barium, caesium, strontium, calcium, chromium, copper, silver, aluminum, iron, and nickel are all of lubricating nature adapted for use as a lubricating media, in accordance with the teachings of my present invention; that combinations of these materials may be used; and, in fact, in treating bearings for use in X-ray generators, I prefer to employ barium as a lubricating film applied upon the bearing surfaces.

Chromium, which normally will not oxidize, may be used in the treatment of bearings for operation in atmosphere or under other oxidizing conditions.

The selected material is applied upon the bearing surfaces, in accordance with my present invention, by vaporizing the same and directing a stream of the vaporized material upon the bearing surfaces to be treated whereby thus to condense the vapor and form a thin film of the material upon the surfaces to be treated. Vaporization and delivery of the material upon the surfaces may be accomplished in any suitable or preferred manner. A supply of the material, for example, may be positioned in a capsule or container having an opening facing the surfaces to be treated, and the material then heated in the capsule in any convenient manner, as by the passage of an electrical current in order to vaporize the material within the capsule and blowing the resulting vapor through the capsule opening and upon the surfaces to be processed. Alternately, the material may be formed as a filamentary wire, in which the desired lubricating element is incorporated, and then passing an electrical current through the wire in order to expel the lubricating medium as a vapor upon the surfaces to be treated. Such wires as thoriated tungsten and alloys of silver and zinc may be utilized in this manner. Heating coils of tungsten wire in pocket shape, with a small quantity of the lubricating medium enclosed in the pocket, may similarly be used. As the tungsten wire is heated to the melting point of the metal so enclosed, an alloy of the lubricating medium with the tungsten wire may be formed on the surfaces of the wire, and this alloy in turn may then be re-evaporated in order to produce a film of the lubricating medium upon the surfaces to be treated. This method is suitable for applying such materials as chromium, difficultly obtainable in metallic state and possessing high melting point.

I prefer, however, in treating bearings for use in X-ray generators, to employ a hollow filamentary wire W, preferably of iron or nickel, containing within the wire a quantity of the lubricating material L, such as pure barium, the hollow wire being weakened by reducing its wall thickness along one side of the wire, as indicated at S. By passing an electrical current through the wire W, the material L may be vaporized

therein, the vapor products being blown out through the weakened wall section S, and of course by supporting the wire with the surface S facing toward the bearing surfaces to be treated, the vaporized medium may be directed directly upon such bearing surfaces.

As shown in the drawing, the anode 13 comprises a cylindrical body having an open end extending in the annular envelope space 25 in position to encircle the seal 33 at the inner end of the reentrant envelope portion 23. The anode thus forms a shield for protecting the seal 33 from deterioration through impingement of stray electrons thereon. The opposite end of the anode body is enclosed, as at 39, and affords a mounting for the target 37. Externally the cylindrical walls of the anode form a seat on which is secured the rotor 41 of an electric motor, the stator 43 of which encircles the envelope extension 21 in cooperative relationship with the rotor 41 whereby to drive the anode within the envelope when the stator 43 is excited from any suitable source of electrical power externally of the envelope.

The spindle 35 extends within the cylindrical anode and carries the bearing means 15, said bearing means comprising in the illustrated embodiment a pair of roller bearings 44 and 46, in spaced-apart position on the spindle portion 35. Each bearing comprises an outer race secured on the anode, and an inner race secured on the spindle portion 35, roller members of any suitable or convenient form, and illustrated as balls, being conventionally retained between the inner and outer race portions.

The anode 13 may, of course, be mounted on the bearing elements in any suitable or preferred fashion, although I have shown the same in the drawing clampingly secured on a cylindrical sleeve-like anode mounting element 85, upon which the cylindrical anode member 13 is fastened, the bearings being enclosed within the hollow bore 87 of the member 85.

The spindle portion 35 is formed with a shoulder 47 providing a seat for the inner race of the bearing 44, the bearing being clamped in said seat and held in position on the stem preferably by means of a nut 51 threaded on the stem. The stem 35 is also threaded to receive clamping nuts 53 and 55 between which is clampingly secured on the stem the inner race of the bearing 46, and a heat shield 57 may be provided for the bearing 46 and supported on the clamping nut 55 in position extending between the target-carrying end of the anode, in which maximum heat is encountered during the operation of the device. This shield serves to protect the bearing from heat radiated from said target-carrying portions of the anode, and tends to equalize the temperature under which the bearings 44 and 46 function.

The spindle 19 is provided with a longitudinally extending duct 59 extending from the outwardly exposed end of the spindle to a point in the spindle portion 35 intermediate the bearings 44 and 46, said duct 59 opening laterally on the portion 35 within the bore or channel 87 of the anode support element 85. The outer end of the duct 57 is enlarged, and has sealed therein a sleeve 61, preferably comprising forty-two percent nickel steel, a material adapted to seal readily with glass.

A lead conductor 63 is arranged in the duct 59 with one end of said conductor extending outwardly of the sleeve 61, and the other end projecting through the end of the duct which opens on the spindle portion 35. Suitable insulating means 65, such as a sleeve of magnesium silicate, or a plurality of glass beads embracing the conductor within the duct 59, is provided for insulating the conductor electrically from the stem 19 in which it is arranged, the outer end of the duct being sealed preferably by means of a glass globule 67 applied within the sleeve 61 around the conductor 63.

Within the space 87 I mount suitable support means for a supply of the lubricating material L, and utilize the conductor 63 and the spindle 19 as circuit forming means for electrically energizing the material L to vaporize the same within the channel 87, in order to process the bearings 15. In the illustrated embodiment this is accomplished by arranging a length of the filamentary tubular wire W on the stem portion 35, said wire being arranged to form loops 69 in position opposite the bearings 15, with the weakened surfaces of the wire portions forming said loops 69 facing toward the bearings. The loops 69 are electrically interconnected, preferably in series, in any suitable fashion, by means of an integral portion of the wire W extending between the loops 69. One of the loops is electrically connected as by soldering or welding the same upon the spindle portion 35, the other loop being electrically connected with the end of the conductor 63 which is exposed within the channel 87. If desired, the spindle 35 may be provided with insulating means for supporting the wire W rigidly in position, although ordinarily additional support is not required since the wire itself has sufficient rigidity to maintain itself in assembled position, at least until after the material L has been flashed in processing the bearing.

It will be seen from the foregoing that by connecting a suitable source of electrical potential between the outwardly exposed end of the conductor 63 and the spindle 19, an electrical heating current may be caused to flow through the wire W in order to raise the temperature of the wire to a point at which the material L vaporizes, in order thus, as heretofore described, to cause the expulsion of vapor through the weakened wall S at the loops 69 and thence upon the bearings.

The bearings preferably are thus processed for the application of a film of the lubricating medium L thereon, after assembly in the envelope 17 and after the envelope has been evacuated, as heretofore described, so that flashing of the material L is accomplished substantially in vacuo and after the envelope 17 has been completely sealed. The flash products, however, will not escape to any detectable extent from the hollow anode. The vaporized products, however, impinging upon the facing surfaces of the bearings, which preferably are rotated during the flashing of the material L, immediately condense upon the surfaces to form a film thereon, the inner face of the film wetting the surface material of the bearing and forming an alloy therewith which holds the film in place. The rotation of the bearings causes substantially all of the surfaces thereof required to be treated to receive the coated film of the lubricating material; and since the flash products are confined substantially within the chamber 87, no migration of such products outwardly of the bearings and the hollow anode is detectable, and the vacuum condition within the envelope is not in any way impaired as a result of the flashing operation.

In order to seal and protect the exposed end of the conductor 63, the outer end of the stem 19 may be threaded, as shown at 71, to receive a cover cap 73, the outer end of which may be threaded as shown, or otherwise finished as desired, said cap being preferably threaded for the reception of heat dissipating means thereon by means of which heat developed at the anode may, in part, be dissipated from the generator by conduction through the anode support sleeve 85, the bearings 15, and the spindle outwardly of the envelope 17.

I have found that bearings treated in accordance with the teachings of my present invention are able to operate substantially without wear and without conventional lubrication throughout extended service periods, under excessive low pressure and high heat conditions. When used in X-ray generators, bearings processed in accordance with my present invention have an extended service life, usually outlasting the normal life of the generator itself.

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 and scope of the invention, nor sacrificing its attendant advantages, the forms herein disclosed being merely for the purpose of demonstrating the invention.

The invention is hereby claimed as follows:

1. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, said working surfaces comprising the alloy of the material of said bearing means with an evaporable metallic substance coated thereon as a condensate from the vapor stage and thereby integrated with the working surfaces for lubricating purposes.

2. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and a film of material comprising evaporable metallic substance condensed upon and alloyed with the material of said working surfaces to form a lubricating layer thereon.

3. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and a metallic substance coated as a thin film on and alloyed with the material of said working surfaces to lubricate said bearing means.

4. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and an alloy film forming lubricating means on said working surfaces and comprising the complex alloy of the material of said working surfaces with a metal or metals having vapor pressure characteristics preventing evaporation thereof to any appreciable extent under the temperature conditions prevailing within the envelope when the generator is in operation.

5. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and a metallic substance coated as a thin film on and alloyed with the material of said working surfaces to lubricate said bearing means, said metallic substance comprising the alloy of the material of said working surfaces with a metal of the class comprising barium, strontium, calcium, caesium, copper, silver, aluminum, chromium, iron and nickel.

6. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and a metallic substance coated as a thin film on and alloyed with the material of said working surfaces to lubricate said bearing means, said metallic substance comprising the complex alloy of the material of said working surfaces with at least two metals of the group comprising barium, strontium, calcium, caesium, copper, silver, aluminum, chromium, iron and nickel.

7. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and a metallic substance coated as a thin film on and alloyed with the material of said working surfaces to lubricate said bearing means, said metallic substance comprising the complex alloy of the material of said working surfaces with barium and a metal of the group comprising strontium, calcium, caesium, copper, silver, aluminum, chromium, iron and nickel.

8. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and a metallic substance coated as a thin film on and alloyed with the material of said working surfaces to lubricate said bearing means, said metallic substance comprising the complex alloy of the material of said working surfaces with aluminum and a metal of the group comprising barium, strontium, calcium, caesium, copper, silver, chromium, iron and nickel.

9. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and a metallic substance coated as a thin film on and alloyed with the material of said working surfaces to lubricate said bearing means, said metallic substance comprising the complex alloy of the material of said working surfaces with chromium and a metal of the group comprising barium, strontium, calcium, caesin, copper, silver, aluminum, iron and nickel.

10. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and barium coated as a thin film on and alloyed with the material of said working surfaces to lubricate said bearing means.

11. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and aluminum coated as a thin film on and alloyed with the material of said working surfaces to lubricate said bearing means.

12. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and chromium coated as a thin film on and alloyed with the material of said working surfaces to lubricate said bearing means.

13. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and barium and aluminum coated as a thin film on and alloyed with the material of said working surfaces to lubricate said bearing means.

14. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and barium and chromium coated as a thin film on and alloyed with the material of said working surfaces to lubricate said bearing means.

15. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and aluminum and chromium coated as a thin film on and alloyed with the material of said working surfaces to lubricate said bearing means.

16. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and metalic means, coated as a thin film on and alloyed with the material of said working surfaces to lubricate said bearing means, comprising barium and a metal having a vapor pressure such that it will not evaporate to any appreciable extent under the temperature conditions prevailing within the envelope when the generator is in operation.

17. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and metallic means, coated as a thin film on and alloyed with the material of said working surfaces to lubricate said bearing means, comprising aluminum and a metal having a vapor pressure such that it will not evaporate to any appreciable extent under the temperature conditions prevailing within the envelope when the generator is in operation.

18. An X-ray generator comprising an evacuated envelope, an electrode, and bearing means having working surfaces turnably supporting said electrode within said envelope, and metallic means, coated as a thin film on and alloyed with the material of said working surfaces to lubricate said bearing means, comprising chromium and a metal having a vapor pressure such that it will not evaporate to any appreciable extent under the temperature conditions prevailing within the envelope when the generator is in operation.

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