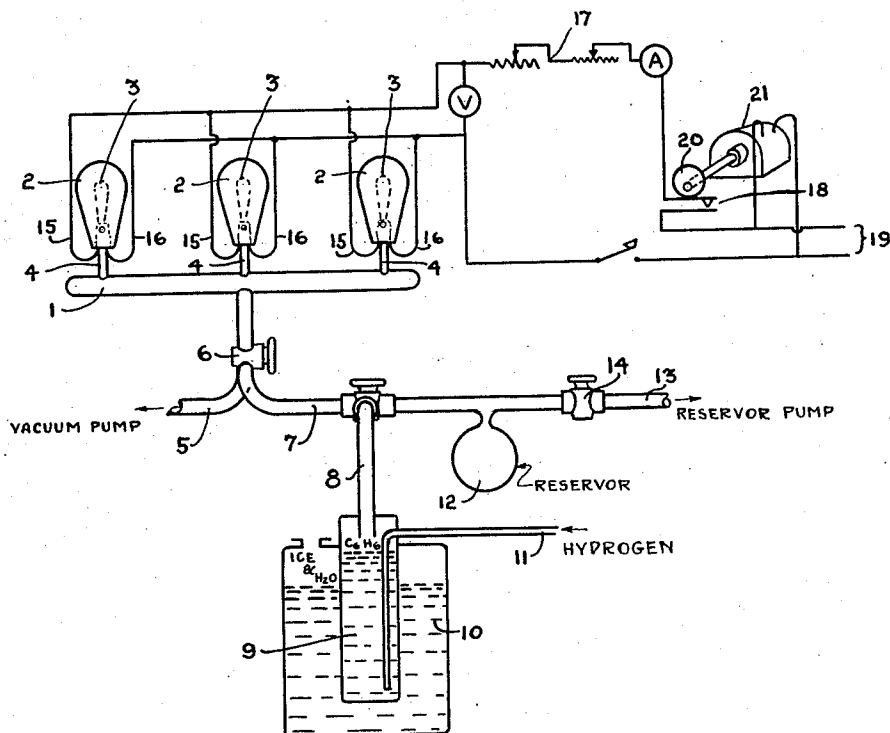


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ACTIVATION OF FILAMENTS  
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## UNITED STATES PATENT OFFICE.

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## ACTIVATION OF FILAMENTS.

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This invention relates to a method and apparatus for activating thoriated tungsten filaments for electron emission purposes and more particularly to the carbonization thereof for the purpose of converting the thorium oxide content thereof to thorium metal.

heated to a temperature above the dissociation point of the tungsten and carbon. As a consequence, the maximum carbonization will be produced at a point between the center and each end of the filament.

It is the practice in the manufacture of thoriated tungsten filament to incorporate into the purified tungsten powder a small percentage of thorium oxide, usually not over 2% and to fabricate such mixture into coherent ductile form as by the process described in Coolidge Patent 1,082,933. When it is desired to employ such filaments for electron emission purposes it is necessary to convert the thorium oxide or a portion thereof to metallic thorium, which material serves as the active electron-emitting constituent. It is not feasible to incorporate the thorium directly into the tungsten in metallic form since it volatilizes from the tungsten during the heat treatments to which the material is subjected in manufacture. Various methods have been proposed for converting the thorium oxide to thorium metal upon completion of the filament, the most practical method being by employing a carbonaceous reducing agent.

Spotty or excess local carbonization is brought about by irregularities in the cross section of the filament. At points where the cross section is small, a higher temperature, known as "hot spots," will be obtained, causing the carbonization to proceed more rapidly at that point than at adjacent points. Inasmuch as the resistance of the filament increases by carbonization, the carbonization at these hot spots usually builds up much more rapidly than at the adjacent cooler portions, so that by the time the main body of the filament has become carbonized to a sufficient degree, there are numerous spots which are very much over-carbonized. This is a serious defect since carbonization causes embrittlement of the filament, rendering it short lived and lowering its resistance to shock or vibration.

It has been proposed heretofore to heat the filament at a high temperature for a few minutes in a low pressure of a carbonaceous vapor, such as anthracene or acetylene, whereby the incandescent filament decomposes the hydrocarbon vapor which comes in contact therewith and effects a chemical combination between the filamentary material and the carbon, probably forming tungsten carbide ( $W_2C$ ). During a subsequent heat treatment, the thorium oxide is reduced to metallic form by the carbide.

Another difficulty inherent in the methods employed heretofore, for carbonizing filaments, is the necessity of employing low pressures of the hydrocarbon vapor. The pressure of the hydrocarbon is quite critical, a slight variation in the pressure causing either over-carbonization or under-carbonization. It is very difficult, however, to obtain accurately, a uniform low gas pressure in the commercial application of the process and to avoid these difficulties it has been necessary to vary the time of carbonization in each instance, thus rendering it difficult to adapt the process to automatic or purely mechanical operations.

Difficulty has resulted from this carbonization process, due to the non-uniformity and spotty nature of the carbonization produced. The lack of uniformity of carbonization is caused by the difference in temperature of the various portions of the filament. The end portions of the filament are at a much lower temperature than the medial portion, due to conduction of heat by the filament supports. Due to this difference in temperature, if the average temperature of the filament is chosen so as to produce the most effective carbonization, the end portions will be at too low a temperature to become effectively carbonized, whereas the central portion may be

One of the objects of the present invention is to avoid the above mentioned difficulties and produce a method of carbonization which is readily adaptable for mechanical operations.

Another object is to provide a method of carbonizing filaments whereby the individual filaments will be more uniformly carbonized throughout their lengths and in which uniformity will be obtained between various filaments.

A still further object is to carbonize filaments in a manner so as to prevent excess local carbide formation and to produce a thorium activated filament which is strong and which will have a long commercial life.

A further object is to provide a suitable apparatus for carrying out the above objects. Other objects and advantages will hereinafter appear.

5 In accordance with the present invention the unactivated filaments are sealed into an envelope in the usual manner and after the tubes have been exhausted, they are filled with a purified gas, such as hydrogen, which  
10 contains a vapor of a hydrocarbon. The filaments are then flashed and allowed to cool in rapid succession so that the filament attains a temperature of about  $2400^{\circ}$  K. for a fraction of a second only at each flashing.  
15 During the major portion of the interval while the filament is heating and cooling, carbon is being deposited thereon, while carbide formation takes place only at the final temperature attained by the filament.  
20 Due to the short period of each flash, there is very little loss of heat, due to radiation to the support wires and the filament is therefore heated substantially to the same temperature throughout its entire length. Consequently, the carbonization proceeds substantially uniform throughout the length of the filament. While the filament is being heated from approximately  $200$  or  $300^{\circ}$  K. to around  $2200^{\circ}$  K. carbon is being deposited  
30 thereon at a substantially uniform rate over the entire surface, since between these temperatures, carbon does not react with the tungsten and there is no carbide formation taking place. During the interval at which  
35 the filament is increasing from about  $2200^{\circ}$  to  $2400^{\circ}$  K. and again decreasing to  $2200^{\circ}$  K. the tungsten reacts with the carbon to form tungsten carbide. However, since the carbon is already present on the filament in a  
40 uniform deposit, when the filament attains this elevated temperature, each portion of the filament will be carbonized to substantially the same extent and spotty condition, due to local over-heating, is prevented. The  
45 period during which the filament is maintained at a carbonizing temperature is extremely short and substantially the only carbonization that takes place is due to the carbon which was deposited thereon, at the low-  
50 temperatures.

In order that the invention may be more fully understood, reference will be had to the accompanying drawing in which the single figure illustrates in somewhat diagrammatic  
55 form, apparatus for carrying out the present invention.

The apparatus shown comprises a manifold 1 to which are attached a number of electron discharge devices 2 having sealed therein, filaments 3 which it is desired to activate.  
60 The discharge devices 2 are joined to the manifold 1 by exhaust tubes 4. A vacuum pump (not shown) is joined to the manifold 1 by a conduit 5 through a two-way valve 6.  
65 The valve 6 also communicates through con-

duits 7 and 8 with a receptacle 9 containing a liquid hydrocarbon. While benzene is preferred as the hydrocarbon, other hydrocarbons of the benzenes series, such as toluene or other non-saturated hydrocarbon liquid  
70 at readily obtainable temperatures, may be employed. In order to maintain the vapor pressure of the hydrocarbon constant, it is immersed in a second receptacle 10 containing a constant temperature medium, such as, for instance, ice water. Hydrogen, from a  
75 line 11, is bubbled through the benzene 9 and saturated with the benzene vapor at the temperature of the cooling medium 10. A reservoir 12 is provided for storage of the carbon  
80 vapor containing hydrogen. A reservoir pump (not shown) for exhausting the reservoir 12 prior to emitting the hydrogen thereto, is joined to the reservoir by a connection  
85 13 controlled by a valve 14. If desired, the reservoir may be omitted and the gas led directly from the mixing chamber 9 to the manifold 1.

In order to flash the filaments 3 intermittently, the leading-in wires 15 and 16 for  
90 each of the filaments are connected through a resistance 17 and a make-and-break device 18 with a source of current 19. The make-and-break device 18 is operated intermittently by a cam 20 driven by any suitable  
95 motor 21.

The operation of the apparatus is as follows. After the apparatus is sealed to the exhaust manifold 1 the valve 6 is adjusted so as to close off the hydrogen line 7 and open  
100 the exhaust pump connection 5 so as to exhaust the tubes. At the same time, the reservoir 12 may be exhausted by the reservoir pump through the valve 14. After the envelopes 2 have been exhausted, hydrogen  
105 bubbled through the benzene 9 is admitted to the envelopes at approximately atmospheric pressure from the reservoir 12, and the motor 21 operated to flash the filaments  
110 intermittently. The filaments are lighted only momentarily by the contact 18 which is maintained in close position for only a small fraction of a second. The resistance 17 is adjusted so that the filaments will be heated to approximately  $2400^{\circ}$  K. in the interval  
115 during which the contact device 18 is closed.

The frequency of the flashing may be varied within wide limits but I have obtained excellent results flashing the filament about  
120 once each second. The number of flashes to which the filaments are subjected depends, of course, upon the size of the filament, the maximum temperature thereof, the duration of the flash, and the pressure or temperature of the hydrocarbon vapor. At the higher  
125 maximum filament temperatures, fewer flashes will be required, as will also be the case when the partial pressure of the hydrocarbon is increased. As a specific example, employing benzene vapor mixed at a temper-  
130

ature of 0° C., and a filament size of approximately 4½ mils, effective carbonization may be effected in about forty flashes, the maximum filament temperature being around 2400° K.

The function of the hydrogen is two-fold; it serves first to regulate the quantity of hydrocarbon vapor admitted to the envelope, and secondly, as a heat transferring medium for rapidly cooling the filament after each flash. By maintaining the temperature of the benzene uniform, the partial pressure of the hydrocarbon taken up by the hydrogen will be sufficiently constant and such that when the hydrogen is employed at approximately atmospheric pressure, it will contain a sufficient quantity of the hydrocarbon vapor to effect the carbonization of the filament.

This process is particularly well adapted for automatic carbonization since a uniform pressure of the hydrocarbon may be easily obtained and maintained; and, by virtue of the intermittent flashing of the filament, the quantity of hydrocarbon obtained in the envelope is not critical and substantially uniform results may be obtained with widely varying partial pressures of the hydrocarbon. It is possible, therefore, to obtain, within permissible limits, the same degree of carbonization with all filaments, simply by flashing them in the hydrocarbon vapor the proper number of times. Variations in original resistance from one filament to another are made negligible by employing a sufficiently high voltage and external series resistance.

While I have described a preferred embodiment of my invention it is to be understood that many modifications and changes may be made therein without departing from the invention and I do not desire to be limited except by the appended claims.

What is claimed is:

1. Method of activating thoriated tungsten filaments comprising intermittently incandescing said filaments in a carbon bearing atmosphere.

2. Method of activating thoriated tungsten filaments comprising momentarily and intermittently heating said filaments to a carbonizing temperature in a carbon bearing atmosphere until the desired carbonization is effected.

3. Method of activating thoriated tungsten filaments comprising subjecting the filaments to a number of high temperature flashes of short duration in a carbon bearing atmosphere.

4. Method of activating thoriated tungsten filaments comprising repeatedly heating the filaments momentarily to a temperature of about 2400° K. in the vapor of a hydrocarbon.

5. Method of activating thoriated tung-

sten filaments comprising repeatedly heating the filaments for a fraction of a second to a temperature of about 2400° K. in a gas containing a carbonaceous material.

6. Method of activating thoriated tungsten filaments comprising heating the filaments to incandescence in a gaseous atmosphere containing a small pressure of a vapor of a carbonaceous material.

7. Method of activating thoriated tungsten filaments comprising alternately depositing carbon substantially uniformly thereon and heating to a sufficiently high temperature to cause a reaction between said carbon and the filaments.

8. Method of activating thoriated tungsten filaments comprising alternately heating the filaments in a carbon vapor at a temperature sufficiently high to effect a deposition of carbon thereon, without carbonization of the filament, and at a temperature sufficiently high to effect such carbonization.

9. Method of activating thoriated tungsten filaments comprising heating the filaments to below about 2200° K. in a carbon bearing atmosphere to deposit carbon thereon and increasing the temperature of the filament above about 2200° K. to effect a combination of the carbon with the filament material.

10. Method of activating thoriated tungsten filaments comprising heating the filaments to below about 2200° K. in a carbon bearing atmosphere to deposit carbon thereon and increasing the temperature of the filament above about 2200° K. to effect a combination of the carbon with the filament material, said latter temperature being maintained only for a brief interval.

11. Apparatus for carbonizing filaments comprising an enclosure for the filaments, means for supplying a carbon bearing atmosphere thereto, and means for intermittently and momentarily supplying a source of current to the filaments to heat the same to incandescence.

12. Apparatus for carbonizing filaments comprising an enclosure for the filaments, means for evacuating the enclosure and supplying a carbon bearing atmosphere thereto, and intermittently operated means for momentarily incandescing the filament.

13. Apparatus for carbonizing filaments comprising an enclosure for the filaments, a source of vacuum and a source of gas containing a hydrocarbon vapor selectively connected to said enclosure and circuit connections for intermittently supplying current to said filament.

In testimony whereof, I have hereunto subscribed my name this 31st day of March, 1927.

GEORGE DEAN O'NEILL.