April 23, 1946. T. G. CRAWFORD 2,399,005

METHOD OF FABRICATING ELECTRIC DISCHARGE DEVICES

Original Filed Feb. 12, 1943 2 Sheets-Sheet 1

Fig. 2.

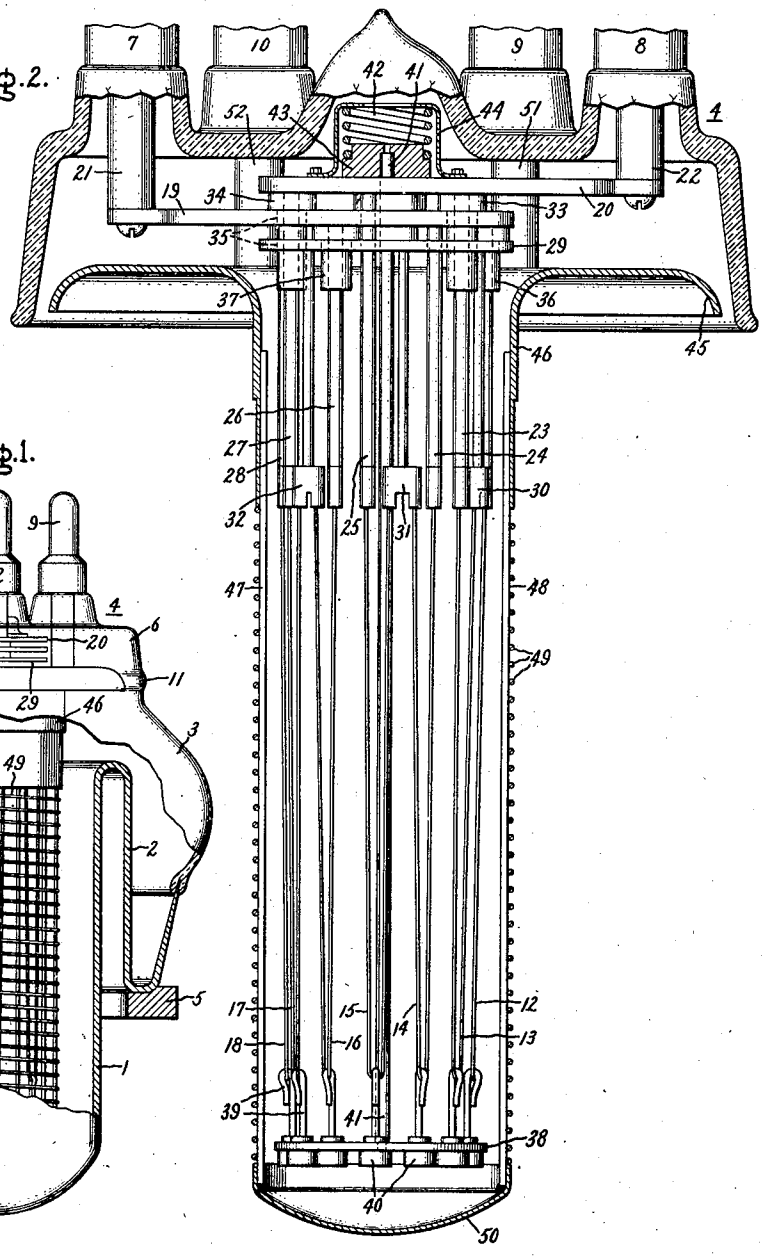

Fig. 1.

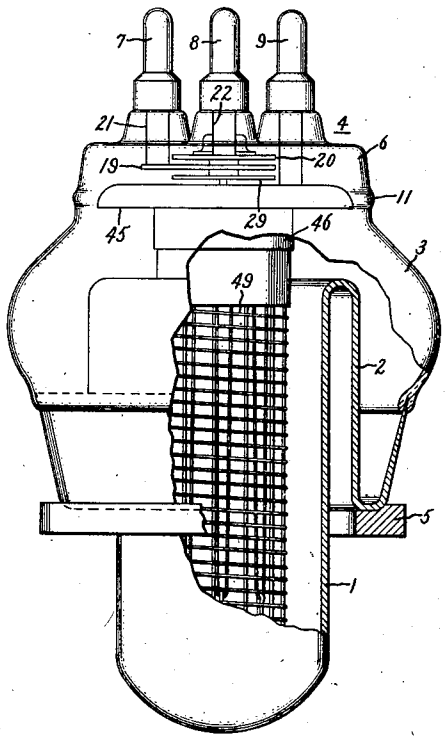

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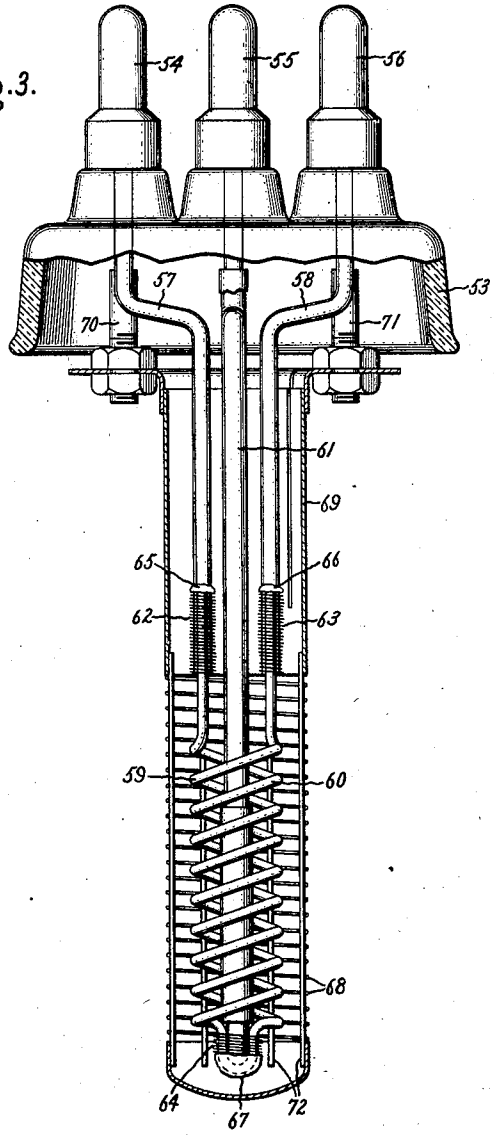
Fig. 3.



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2,399,005

METHOD OF FABRICATING ELECTRIC DISCHARGE DEVICES

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Original application February 12, 1943, Serial No. 475,626. Divided and this application March 31, 1944, Serial No. 528,906

2 Claims. (Cl. 316—1)

My invention relates to electric discharge devices and improved methods of fabricating the same, and more particularly to electric discharge devices of the high vacuum type employing thermionic cathodes peculiarly adaptable for operation at high voltage and current. This application is a division of my application Serial No. 475,626, filed February 12, 1943, entitled "Electric discharge devices and methods of fabrication" and assigned to the assignee of the present application.

It has been appreciated for some time that it is desirable in electric discharge devices of the high vacuum type to employ materials for the thermionic cathodes thereof which are readily capable of supplying the requisite amount of current and which are not subjected to inordinate rates of deterioration due to oxidation or disintegration by ionic bombardment. For example, in United States Letters Patent No. 1,529,597, granted March 10, 1925, upon an application of Irving Langmuir, there is disclosed a method for the carbonization of thoriated tungsten filaments whereby the presence of carbon in definitely limited amounts prevents not only re-oxidation of the active thorium material but also beneficially reduces thoria to the active state. In accordance with the teachings of my invention described hereinafter, I provide new and improved structures for electric discharge devices, and methods of manufacture or preparation, whereby the electric discharge devices are capable of meeting severe load requirements such as high voltage and current conditions, and wherein the structure and method of manufacture are peculiarly adaptable to factory methods and procedure.

It is an object of my invention to provide new and improved methods of manufacturing or fabricating electric discharge devices of the high vacuum type.

It is a further object of my invention to provide new and improved methods of pre-carbonizing filamentary elements or cathodes such as thoriated tungsten cathodes for high vacuum electric discharge devices.

It is a still further object of my invention to provide new and improved methods of pre-carbonizing filamentary cathode elements for high vacuum electric discharge devices and which afford numerous advantages, some of which include uniformity of resistance of the respective elements, substantial freedom from free carbon deposits in inaccessible places, constant or uniform filament resistance, avoidance of the requirement of subjecting the electrode mounts generally to the high flashing temperatures previously required, and the incident reduction in strains produced on the electrode mount.

In accordance with my invention, I provide new and improved methods of pre-carbonizing and fabricating a plurality of thoriated tungsten filaments into an electrode assembly. The filamentary cathode elements are heated in a hydrocarbon or carbonaceous atmosphere to a temperature of substantially 2500 or 2700° C. for a period of time ranging from 20 to 60 seconds to effect the carbonization of the thoriated tungsten of the elements. The elements are then permitted to cool and the resistances thereof are measured for the purpose of selecting those elements having substantially equal or uniform resistances. The selected elements are then mounted as part of the electrode stem construction and are attached thereto by a suitable operation such as a resistance or arc weld.

For a better understanding of my invention, reference may be had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims. Fig. 1 illustrates in general outline the type of electric discharge device to which my invention may be applied and shows the enclosing envelope partially broken away and the enclosed electrode structure including the filamentary cathode and the grid structure. Fig. 2 illustrates in enlarged form the stem construction including the supported cathode and grid. Fig. 3 illustrates an alternative embodiment wherein the filamentary cathode comprises a pair of oppositely wound helical elements supported from the stem construction.

Referring now to Fig. 1 of the drawings, I have there illustrated my invention as applied to a high power transmitting electric discharge device which includes an externally cooled anode 1 of tubular configuration which is closed at one end and which merges at its other end into a reversely bent portion 2. The edge of the latter portion is sealed to a glass bulb 3 which, in turn, is sealed to a vitreous part of the stem construction 4. The anode 1, the glass bulb 3 and the stem construction 4 constitute in combination a vacuum-tight envelope of the electric discharge device. A flanged member 5 joined to the reversely bent anode portion 2 serves during use of the tube to support the tube or electric discharge device envelope and to connect it with a cooling jacket (not shown) for the anode.

At its upper end, the glass bulb 3 terminates in a flat vitreous cap 6 which supports a plurality of externally accessible terminals or terminal posts 7–10, inclusive, only three of which are shown in Fig. 1. Each of these terminal posts may comprise a cup-like member comprising an elongated tubular portion and a relatively large end portion, these parts being respectively supported by and sealed to the vitreous part of the stem construction 4. The details of the electrode construction, and particularly the filamentary

cathode and grid structure, may be more fully appreciated by referring to Fig. 2.

The electrode mount and stem construction shown in the enlarged view of Fig. 2 comprises vitreous part 6 which is sealed at 11 to the glass envelope 3 shown in Fig. 1. I provide a thermionic cathode comprising a plurality of filamentary elements which may have a hairpin configuration and which are centrally positioned within the metal anode 1. For example, I provide a plurality of hairpin filamentary cathode elements arranged annularly, thereby forming a symmetrical mesh of electron emissive surfaces. Only elements 12—18 are illustrated in Fig. 2 and it will be appreciated that other elements, not shown, complete the electron emissive structure of the cathode.

I provide means supported by and attached to the stem construction 4 for supporting the filamentary cathode elements 12—18 in spaced relation within the anode 1, and also in spaced relation with respect to grid structure to be described presently. More particularly, I provide a pair of metallic plates or disks 19 and 20 which are spaced and electrically insulated, and which are respectively connected to terminal posts 7 and 8 through rigid conductors 21 and 22. A plurality of rigid metallic connectors 23–28, inclusive, are employed to connect one open end of each adjacent pair of elements 12—18, respectively, to plates 19 and 20 so that adjacent pairs may be energized in series relation from a source connected to terminal posts 7 and 8. For example, elements 14 and 15 are connected in series relation through connectors 24 and 25, the former of which is connected to plate 19 and the latter of which is connected to plate 20. In like manner, other pairs of the filamentary cathode elements are connected to plates 19 and 20. In this manner, the filamentary heating elements are energized in a parallel-series relationship, that is, the various individual pairs of serially connected elements are energized in parallel.

I also employ means for joining the other open ends of adjacent pairs of the filamentary heating elements and for equalizing the potentials of the common junctures of adjacent pairs. This means may take the form of a metallic plate 29 spaced and electrically insulated from plates 19 and 20 and which supports a plurality of connectors 30—32 which are conductively connected to plate 29 and to which the cathode elements are welded.

In order to provide a rigid mechanical construction, as well as the requisite electrical insulation, I provide a plurality of tubular insulators which extend through and receive the connectors 23—28 and connectors 30—32. For example, suitable insulators, such as quartz insulators 33 and 34, extend through apertures 35 in plates 19 and 29, thereby insulating connectors 23 and 27 therefrom. Similarly, tubular vitreous or quartz insulators 36 and 37 extend through apertures in plate 29 and insulate connectors therefrom.

Insulators 33, 34, 36 and 37, which are merely representative of the plurality of insulators so employed, may be constructed, as illustrated, to afford appreciable shoulders which permit accurate and firm spacing of plates 19, 20 and 29.

At the lower end of the cathode structure, I provide an anchor plate assembly which serves to maintain the filamentary cathode elements in the desired rigid spaced relation with respect to the other electrodes of the discharge device. The anchor plate assembly comprises a metallic plate 38 which supports a plurality of annularly spaced retaining members, such as hooks 39, which are insulated from plate 38 by means of a plurality of individual insulators 40 preferably constructed of quartz.

As a means for firmly positioning the anchor plate assembly, I provide an axial or longitudinal rod 41 which is attached to plate 38 at its lower extremity and which is supported from plate 20. I also provide means for exerting an axial or longitudinal force on rod 41 to firmly position the anchor plate assembly and, in turn, exert a longitudinal or axial force on the filamentary cathode elements 12—18. This means may be of resilient character comprising a compression spring 42 which engages a bushing 43 provided with a shoulder adapted to receive the upper extremity of rod 41. Spring 42 is held in position in a compressed state by means of a metallic cap 44 which is secured to plate 20.

The stem construction also includes a metallic plate 45 which is provided with an annular flanged part 46 which, in turn, supports a plurality of vertical or longitudinal conductors 47 and 48 which serve as support or positioning members for a helically wound grid 49. The lower ends of the vertical conductors 47 and 48 may be closed by a metal cap 50.

Plate 45, which supports the above-described grid structure, may be attached to a pair of rigid conductors 51 and 52 which are respectively connected to terminal posts 9 and 10. If desired, a single grid supporting conductor and a single terminal post may be employed.

The individual filamentary cathode elements, of which elements 12—18 are representative, are pre-carbonized before mounting or assembling in the structure shown in Fig. 2. These elements are flashed and pre-carbonized, before mounting, in an atmosphere of a hydrocarbon of carbonaceous vapor. For example, the elements may be supported by a fixture (not shown) positioned within a compartment or chamber to which there is supplied a desired hydrocarbon vapor, such as a mixture of benzene and hydrogen, in the proper proportions to effect the desired carbonization of the elements within a predetermined interval of time. The temperature of the elements is raised by transmitting through the elements current of a predetermined value to effect the desired carbonization. For example, the temperature of the cathode elements may be raised to a value within the neighborhood of 2500 to 2700° C. and exposed to the hydrocarbon vapor for a period of time ranging from 25 to 45 seconds.

Of course, in carrying out the method in accordance with my invention time is allowed for the elements to assume the desired temperature, the period of time depending upon the size of the elements undergoing treatment, the resistance thereof, and the current which is transmitted therethrough. As an example of the period of time required in the process of flashing and pre-carbonizing for a particular sized thoriated tungsten filamentary element, I have found that a current of 100 amperes should be supplied to the element and an interval of 30 seconds allowed for the element to attain the desired flashing and pre-carbonizing temperature. The elements are maintained at that temperature for a period of 25 seconds, at the expiration of which the elements are permitted to cool for a period of time approximating two minutes, whereafter the elements may be mounted, that is welded to the connectors of which connectors 23–28, inclusive, are

representative. Of course, prior to welding to these connectors, the filamentary cathode elements are threaded through the eyes provided by hooks 39.

As an intermediate step before assembly in the electrode mount shown in Fig. 2, resistances of the individual cathode elements are measured for the purpose of selecting and using in a particular discharge device, those elements having substantially the same or uniform resistances. In this manner, the voltage drop along the individual elements is maintained substantially equal, thereby making it possible to provide a cathode emitting structure wherein the current emission from individual elements is substantially uniform. The advantages of such uniformity in electron emission from a directly heated cathode is well appreciated, the advantages including increased life of the cathode structure and improved operation of the electric discharge device.

Another advantage incident to the individual precarbonization of the various cathode elements is the feature which permits choice of the elements to establish small tolerances in resistances simply by selection. In this relation, the cathode elements and the grid structure, since the cathode elements have been pre-carbonized apart from the electrode mount, may be maintained or kept free of extraneous particles and no large quantities of free carbon are deposited in inaccessible places. The presence of extremely large quantities of free carbon on the electrode mount, or on parts thereof, would cause high voltage gradients and consequently would cause breakdown at relatively high voltages.

A still further advantage of apparatus built in accordance with my invention is that the electrode mounts, which are relatively expensive, are not exposed to the high flashing temperature previously required in the manufacture of devices of this character, since the flashing of the cathode elements has been performed apart from the electrode mount. A still further advantage in this connection is that incident to the same procedure in which the individual preflashing or carbonization of the cathode elements does not necessitate the subjection of the electrode mount to great mechanical strains which, according to the prior art arrangements, were present when the elements were flashed assembled with and as parts of the electrode mounts.

In Fig. 3 of the drawings there is illustrated a further modification of my invention showing an electrode mount and stem assembly which may be employed in an electric discharge device of the general configuration shown in Fig. 1. The stem construction comprises a vitreous part 53 which may be sealed to a glass bulb, such as that shown in Fig. 1, and supports terminal posts 54, 55 and 56 in sealed relation thereto. Terminal posts for the grid structure are not illustrated in this view. Lead-in conductors 57 and 58, of rigid construction, support a pair of individually and separately pre-carbonized cathode heating elements of helical configuration which are oppositely wound and which together constitute the directly heated cathode of an electric discharge device. A further lead-in conductor 61, which is connected to terminal post 55, extends longitudinally or axially the electrode mount and serves as a central supporting element as well as an electrical connection to the lower ends of the helical elements 59 and 60.

In the assembly operation, elements 59 and 60 may be bound to lead-in conductors 57 and 58 by means of refractory binding wires 62 and 63 and, in like manner, the lower ends of elements 59 and 60 may be bound to conductor 61 and to each other by means of a refractory binding wire 64. After assembly, the elements 59 and 60 may be arc welded at places indicated by numerals 65, 66 and 67 to establish low resistance electrical connections between the elements and the various lead-in conductors.

A helical grid 68 is supported from a flanged cylinder 69 which, in turn, is supported by conductors 70 and 71, either of which, or both of which, may be connected to terminal posts not shown. The helical grid 68 is maintained in the desired position by means of a plurality of longitudinal or vertical conductors 72.

Helical cathode elements 59 and 60 may also be flashed or pre-carbonized in accordance with the above-described method and after pre-carbonization may be assembled as parts of the electrode mount. The advantages of the above-described method also apply to the construction shown in Fig. 3.

In the foregoing specification and in the appended claims the word "pre-carbonized" is employed to designate elements that are carbonized prior to the time that they are secured to an electrode mounting or stem mounting which forms a part of the discharge device as distinguished from the usual construction in which the cathode elements are secured to the electrode mounting and the mounted elements later carbonized.

While I have shown and described my invention as applied to electric discharge devices of a particular character, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. The method of constructing a thermionic cathode for an electric discharge device including a cathode element and a mount therefor which comprises the steps of, first, forming a thoriated tungsten cathode element into a desired shape, then heating said element apart from said mount in an atmosphere of a hydrocarbon vapor for a period of time sufficient to produce carbonization of a substantial portion of the cross section of said element, and then securing said element to said mount.

2. The method of constructing a thermionic cathode for an electric discharge device including a plurality of thermionic cathode elements and a mount therefor which comprises the steps of, first, forming a plurality of thermionic cathode elements into a desired shape, then heating said elements apart from said mount in an atmosphere of a hydrocarbon vapor for a period of time and to a temperature sufficient to produce carbonization of a substantial portion of the cross section of said elements, then cooling said elements, measuring the resistance of individual elements for the purpose of utilizing only those elements having resistances lying within a predetermined range, and then securing selected elements to said mount.

THOMAS G. CRAWFORD.