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PRESSURIZED ALKALI-METAL TUBES

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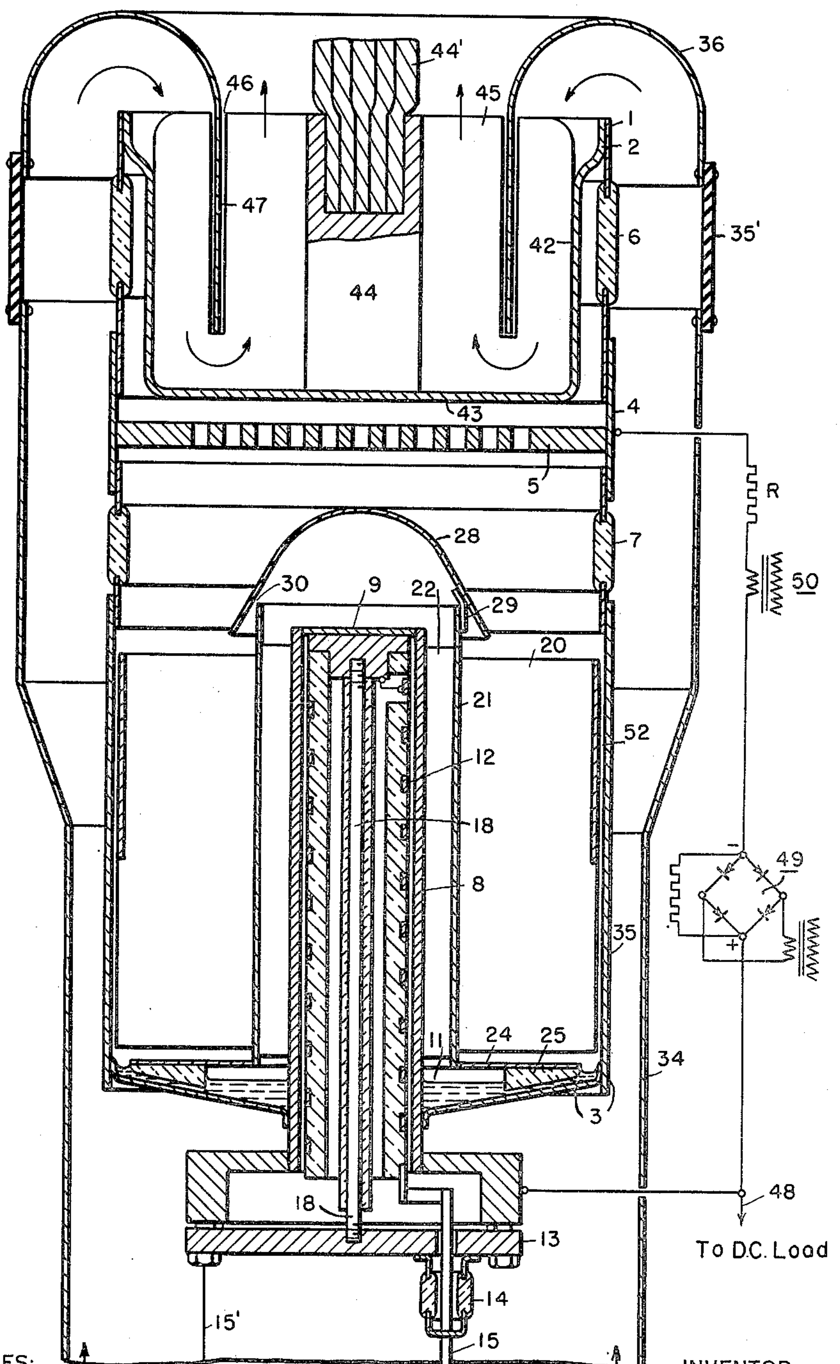

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PRESSURIZED ALKALI-METAL TUBE

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15 Claims. (Cl. 313—227)

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My invention relates to vapor-electric devices or tubes, and particularly to a low-arc-drop hot-cathode arc-discharge device using a vaporizable discharge-metal selected from the alkali-metal group consisting of cesium, rubidium and potassium. The present invention is an improvement over the vapor-electric devices which are described and claimed in an application of August P. Colaiaco and myself, Serial No. 144,354, filed February 15, 1950.

It is well known that the breakdown-voltage of an evacuated or low-pressure gap-device is a function of the *pd* product, where *p* is the pressure and *d* the distance between electrodes. At extremely low values of this product, the breakdown-voltage is very high, up into the thousands of volts, but as this product increases the breakdown-voltage rapidly falls until it reaches a minimum breakdown-voltage, after which any further increase in the *pd* product will cause the breakdown-voltage to rise again, slowly at first, and later on more rapidly. The minimum breakdown-voltage is of the order of some 200 to 500 volts, depending upon the gaseous medium in the space separating the electrodes, and the pressure-distance value *pd* at which this minimum breakdown-voltage occurs is also variable, depending upon the gaseous material. When the gaseous medium consists substantially entirely of the vapor of a vaporizable cathode-metal or discharge-metal, the pressure *p*, in the *pd* product, will be the vapor-pressure of the metal at the coolest internal temperature of the tube, during the operation of the device, or the condensation-temperature of the discharge-metal. The curve which plots the vapor-pressure of different metals, as a function of temperature, is a characteristic curve of the metal, which differs according to the metal.

As in the case of previously known mercury-pool rectifiers, it has been desirable, heretofore, to design alkali-metal rectifiers for operation high up on the low-pressure side of the breakdown-*pd* curve, in order to make the rectifier have as high a factor of safety as possible, in regard to its ability to hold to the negative voltage which is impressed upon the anode during the nonconducting periods of the rectifier. In this way, the danger of backfires is greatly reduced. This means the use of a low value of the *pd* product, that is, a low value of the anode-to-cathode spacing-distance *d*, and a low value of the vapor-pressure *p*.

However, in the case of a hot-cathode alkali-metal rectifier-tube, the ability of the device to

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carry heavy load-currents depends upon the rate at which the alkali-metal vapor may be carried to the surface of the heated cathode, so as to maintain a monomolecular alkali-metal layer thereon. There is thus a conflict in requirements, since the provision of a high current-carrying ability requires the maintenance of as high a vapor-pressure *p* as is practicable, whereas the provision of a high factor of safety against backfires requires as low a vapor-pressure *p* as is practicable.

My present invention, in brief, involves, as its outstanding feature, the provision of a blast of alkali-metal vapor which acts as a diffusion pump or ejector for causing a greater vapor-pressure in the space in which the heated cathode-surface is located, while using a lower vapor-pressure in the region surrounding the anode, so as to make it possible for the anode to hold a relatively high negative voltage, without breakdown, during the nonconducting periods of the tube.

With the foregoing and other objects in view, my invention consists in the systems, combinations, structures, parts, and methods of design and operation, hereinafter described, and illustrated in the accompanying drawing, the single figure of which is a somewhat diagrammatic simplified cross-sectional view of an exemplary form of tube-structure embodying my present invention, with a diagrammatic representation of an illustrative grid-control circuit which might be used.

As shown in the drawing, my vapor-electric device has an evacuated container or enclosure-means **1** including a metal anode-portion **2** at the top, and a metal cathode-portion **3** at the bottom. In many or most cases, also, the enclosure-means **1** will include an intermediate tubular side-wall portion **4** which carries a massive perforated metal barrier-grid **5** in good thermal and electrical contact therewith, said barrier-grid being disposed between the active portions of the anode and the cathode, respectively, as described and claimed in an application of Robert J. Ballard and myself, Serial No. 205,899, filed January 13, 1951. In all cases, the enclosure-means **1** includes insulating seals between the several metal parts, such as the anode-to-grid seal **6** between the anode and grid portions **2** and **4**, and the grid-to-cathode seal **7** between the grid and cathode portions **4** and **3**.

In the illustrated form of embodiment of my invention, the bottom end-wall of the cathode-end **3** of the enclosure-means **1** is provided with a tubular re-entrant cathode-portion 8, which is provided with a hermetically closed inner end 9, which is spaced below the barrier or grid 5. The tube contains a quantity of a vaporizable discharge-metal which is shown in the form of a pool or reservoir 11 of an alkali-metal which is chosen from the group comprising cesium, rubidium, and potassium, this pool or reservoir being shown at the bottom of the cathode-portion 3. The re-entrant cathode-portion 8 is heated to a suitable operating-temperature in the range around 700 or 800° C., by means of a removable heater 12, which is preferably enclosed in a vacuum-tight enclosure which is sealed by a removable bottom closure-member 13 having an insulating seal 14 through which one of the heater-leads 15 may be passed. The other heater-lead 15′ may be connected to the closure-plate 13, which may be connected to the inner end of the heater 12 by means of a vertical rod 18.

As is common in the hot-cathode type of alkali-metal rectifier, the cathode is provided with a finned portion, for increasing the amount of active cathode-surface, which is concentrated in a relatively small space. In the illustrated form of embodiment of my invention, the cathode-fins are shown in the form of a large number of vertical radially extending cathode-fins 20. The cathode-fins 20 must be in good thermal and electrical relation to the heated cathode-tube 8. In accordance with my present invention, in order to provide a chimney through which alkali-metal vapors can be supplied to the top end of the re-entrant cathode-tube 8, I preferably supply a second tubular hot-cathode member 21, which surrounds, and is spaced from, the re-entrant cathode-tube 8, being connected in good thermal and electrical relation thereto by means of a plurality of vertically extending fins or spacers 22 which are disposed between the two cathode-tubes 8 and 21. The cathode-fins 20 are secured to the outer surface of the cathode-tube 21, so that the heat from the heater 12 passes from the re-entrant tube 8 through the heat-carrying spacer-fins 22 to the cathode-tube 21, and thence to the cathode-fins 20, thereby heating the cathode-fins.

The portion of the alkali-metal pool which surrounds the re-entrant cathode-tube 8 is heated to a vaporizing temperature by this tube, and in order to cause this vapor to rise upwardly in the space between the two cathode-tubes 8 and 21, it is necessary to confine this heated inner portion of the pool. To this end, I have shown, secured to the bottom end of the cathode-tube 21, a metal washer 24 which extends outwardly therefrom, and which carries a depending heat-insulating ring 25 which dips down into the alkali-metal pool 11, extending nearly to the bottom wall of the cathode-portion 3 of the enclosure. Thus, the metal vapors from the heated inner portion of the pool 11 pass up between the spacer-fins 22 between the inner and outer cathode-tubes 8 and 21.

The heat from the re-entrant cathode-tube 8 causes a high vapor-pressure which produces a blast of alkali-metal vapor which passes up to the top of the re-entrant tube 8, and at this point the direction of vapor-flow is changed, as by means of a dome-shaped metal cap 28, which is held spaced closely above the top edge of the cathode-tube 21, as by means of one or more supporting-wires 29, so as to provide a narrow annular space 30 through which the vapor-blast is directed downwardly at a high velocity, toward the cathode-fins 20, thus serving as a diffusion-pump, or ejector for drawing the internal vapor, within the rectifier, down away from the upper region, in which the anode 2 and the grid 5 are located.

Thus a relatively low vapor-pressure is maintained in the upper region of the rectifier-tube, while a relatively higher vapor-pressure is produced in the lower region, around the cathode-fins 20. By reason of this pumping action, I am thus enabled to maintain a relatively high vapor-pressure p in the region of the cathode-fins 20, where a high vapor-pressure is needed in order to increase the maximum-current rating of the rectifier, while at the same time the rectifier is operated with a relatively low vapor-pressure p in the anode region, or in the anode-to-grid region, where a low vapor-pressure is needed in order to enable the tube to maintain a high breakdown voltage which is needed during the nonconducting periods of the rectifier.

It is necessary to provide some cooling-means for the tube, so that some portion of the tube is maintained at a low temperature of the order of from 200 to 250° C., more or less, at which the metal vapor within the tube is condensed, thus determining the average vapor-pressure within the tube. It is usually necessary, also, to cool the anode-portion 2, to some temperature which is cool enough to prevent any substantial electron-emission from the anode, this anode-temperature being preferably slightly higher than the coolest point or condensation-temperature, in order to prevent condensation of the alkali-metal vapor on the anode.

While natural cooling could sometimes be used, for this purpose, I prefer to use an artificially induced blast of cooling-air (or other cooling-fluid), as indicated by the arrows 33, which are intended to illustrate any suitable means, either a natural chimney-draft, or blower-means (not shown), for causing an upward movement of cooling-air surrounding the rectifier. As shown, this cooling-air is confined by a chimney-like enclosure 34 which surrounds the lower portion of the vertical cylindrical-wall portion 35 of the cathode-part 3 of the tube-enclosure, in closely spaced relation thereto, so as to cool the same. The chimney 34 also extends upwardly beyond the top of the enclosure 1, preferably being provided with an insulating tubular chimney section 35′, to insulate the bottom chimney-portion 34 from the top chimney-portion 36, which is shown in the form of a metal spinning.

The anode-portion 2, which is located at the top of the enclosure 1, is preferably provided with a re-entrant metal anode-portion 42, having a closed bottom end 43 which constitutes the active anode-surface of the rectifier. Centrally secured to the active anode-plate 43 is a massive upstanding copper pillar 44 which has good thermal and electrical connection thereto, and an anode-lead cable 44′ is secured in the top of this copper pillar 44. The copper pillar 44 carries a plurality of radially extending fins 45, which are in good thermal contact with the pillar 44, and which may also be in good thermal contact with the re-entrant anode-portion 42—43. These fins 45 are illustrated as being provided with deep slots 46, extending down from their tops; and the metal spinning 36 of the air-directing chimney is provided with a bent-down portion 47 which enters down into these slots 46 and causes the cooling-air to circulate downwardly into the re-entrant anode-portion **42**, and thence upwardly out of the device.

Since the cooling-air passes the lower cylindrical cathode-portion **35** first, it makes this portion the coolest point in the device, so that the alkali-metal vapor is condensed on the inner wall of this lower cylindrical cathode-member **35**, from which point the condensed material returns to the cathode pool **11**. The anode **42—43** is also cooled, but since the cooling-air is heated in passing over the cathode outer-wall surface **35**, the anode **42—43** is not cooled to quite as low a temperature as the cathode wall-surface **35**. It will be understood that any cooling-means, which serves the general purpose above outlined, will be satisfactory.

Any suitable grid-circuit means may be used. A common form of grid-control is shown, whereby the grid **5** is connected to the cathode-lead **48** of the device, through a negative-bias means **49**, an alternating-current grid-voltage source **50**, and a grid-resistance R, so as to cause the grid **5** to permit the firing of the tube at a desired point in the positive voltage-wave which is applied to the anode **42—43**.

In the operation of my device, a strong blast of alkali-metal vapor is supplied from the alkali-metal pool or reservoir **11** to the diffuser-gap **30**, for producing a downwardly directed vapor-blast which causes a greater vapor-pressure in the space occupied by the cathode-fins **20** than in the space near the anode end of the device. If desired, the upper halves of the cathode-fins **20** may be surrounded by a cylindrical heat-insulating shield **52**, for preventing too much cooling of the vapor on the top part of the cathode-fins **20**.

Any means or construction which accomplishes the above-described general ends is contemplated, within the scope of my present invention. The resulting high-pressure region around the cathode-fins increases the maximum-current rating of the tube many times, for any given electron-emitting cathode-surface area, thus enabling a given size of tube to carry much more current, or making it possible to make a tube of a given current-rating much smaller than heretofore. At the same time, the low vapor-pressure p in the region around the anode **43** and the grid **5** enables the tube to maintain a high breakdown-voltage for preventing backfiring during the non-conducting periods of the tube, when a high negative voltage is applied to the anode **42**.

While I have described my invention in a single illustrative form of embodiment, I wish it to be understood that my invention is not limited to the precise details shown, as it is obvious that any means or details might be used, for accomplishing the general novel purposes which I have described. I desire, therefore, that the appended claims shall be accorded the broadest construction consistent with their language.

I claim as my invention:

1. A vapor-electric device having an evacuated enclosure-means including a metal anode-portion of the enclosure-means at one end of the device, a metal cathode-portion of the enclosure-means at the other end of the device, and an insulating sealing-means between said anode and cathode portions, said metal cathode-portion including a metal tubular cathode-member and metal cathode-fins carried by said metal tubular cathode-member in good thermal and electrical relation thereto, said cathode-fins extending into the space within the device to increase the effective cathode surface-area in the device, a quantity of a vaporizable discharge-metal within the device, said vaporizable discharge-metal being selected from the group comprising cesium, rubidium and potassium, means for heating said tubular cathode-member and said quantity of vaporizable discharge-metal, means for providing a vapor-duct from said quantity of vaporizable discharge-metal to the anode end of said cathode-fins, and means disposed at the exit-end of said vapor-duct for providing an ejector for causing a greater vapor-pressure in the space occupied by the cathode-fins than in the space near the anode end of the device.

2. The invention as defined in claim 1, characterized by said device including a condensing-surface for condensing vaporized discharge-metal and returning the same to the quantity of vaporizable discharge-metal, and means for cooling said condensing-surface.

3. The invention as defined in claim 1, characterized by said device having a perforated barrier disposed in spaced relation to the anode in such position as to shield said anode from the pressurized space occupied by the cathode-fins.

4. The invention as defined in claim 1, characterized by said device having an insulated perforated barrier-grid disposed in spaced relation to the anode in such position as to shield said anode from the pressurized space occupied by the cathode-fins.

5. A vapor-electric device having an evacuated enclosure-means including a metal anode-portion of the enclosure-means at the top of the device, a metal cathode-portion of the enclosure-means at the bottom of the device, and an insulating sealing-means between said anode and cathode portions, said metal cathode-portion including a metal tubular cathode-member and metal cathode-fins carried by said metal tubular cathode-member in good thermal and electrical relation thereto, said cathode-fins extending into the space within the device to increase the effective cathode surface-area in the device, a quantity of a vaporizable discharge-metal disposed at the bottom of the evacuated enclosure-means, said vaporizable discharge-metal being selected from the group comprising cesium, rubidium and potassium, means for heating said tubular cathode-member and said quantity of vaporizable discharge-metal, means for providing a vapor-duct from said quantity of vaporizable discharge-metal to the anode end of said cathode-fins, and means disposed at the exit-end of said vapor-duct for providing an ejector for causing a greater vapor-pressure in the space occupied by the cathode-fins than in the space near the anode end of the device.

6. The invention as defined in claim 5, characterized by said device including a condensing-surface for condensing vaporized discharge-metal and returning the same to the quantity of vaporizable discharge-metal, and means for cooling said condensing-surface.

7. The invention as defined in claim 5, characterized by said device having a perforated barrier disposed in spaced relation to the anode in such position as to shield said anode from the pressurized space occupied by the cathode-fins.

8. The invention as defined in claim 5, characterized by said device having an insulated perforated barrier-grid disposed in spaced relation to the anode in such position as to shield said anode from the pressurized space occupied by the cathode-fins.

9. A vapor-electric device having an evacuated enclosure-means including a metal anode-portion of the enclosure-means at one end of the device, a metal cathode-portion of the enclosure-means at the other end of the device, and an insulating sealing-means between said anode and cathode portions, the end-wall of said cathode-portion of the enclosure-means including a metal tubular re-entrant cathode-portion having a closed inner end which is spaced from the anode-portion of the device, cathode-fins disposed outside of said re-entrant cathode-portion in good thermal and electrical relation thereto, a quantity of a vaporizable discharge-metal within the device, said vaporizable discharge-metal being selected from the group comprising cesium, rubidium and potassium, means for heating said re-entrant cathode-portion and said quantity of vaporizable discharge-metal, means for providing a vapor-duct from said quantity of vaporizable discharge-metal to the inner end of said re-entrant cathode-portion, and means disposed at the exit-end of said vapor-duct for providing an ejector for causing a greater vapor-pressure in the space occupied by the cathode-fins than in the space near the anode end of the device.

10. The invention as defined in claim 9, characterized by said device having a perforated barrier disposed in spaced relation to the anode in such position as to shield said anode from the pressurized space occupied by the cathode-fins.

11. The invention as defined in claim 9, characterized by said device having an insulated perforated barrier-grid disposed in spaced relation to the anode in such position as to shield said anode from the pressurized space occupied by the cathode-fins.

12. The invention as defined in claim 11, characterized by the metal cathode-portion of the evacuated enclosure-means including metal fin-surrounding tubular side-walls surrounding, and spaced from, at least a portion of the cathode-fins at the cathode end of the device, and further characterized by said evacuated enclosure-means including separate metal grid-carrying tubular side-walls carrying said perforated barrier-grid in good thermal and electrical contact therewith, insulating sealing-means between the cathode end of said grid-carrying tubular side-walls and the fin-surrounding tubular side-walls, and other insulating sealing-means between the anode end of said grid-carrying tubular side-walls and the metal anode-portion of the enclosure-means.

13. The invention as defined in claim 9, characterized by the metal anode-portion of the evacuated enclosure-means having a re-entrant anode-portion extending into the device, and the metal cathode-portion of the evacuated enclosure-means including metal tubular side-walls surrounding, and spaced from, at least a portion of the cathode-fins at the cathode end of the device, in combination with means for circulating a cooling-fluid first into heat-exchanging relation to said tubular side-walls of the cathode-portion, and then into said re-entrant anode portion into heat-exchanging relation to the inner end of said re-entrant anode-portion, and thence out of the device.

14. A vapor-electric device having an evacuated enclosure-means including a metal anode-portion of the enclosure-means at the top of the device, a metal cathode-portion of the enclosure-means at the bottom of the device, and an insulating sealing-means between said anode and cathode portions, the end-wall of said cathode-portion of the enclosure-means including a metal tubular re-entrant cathode-portion having a closed inner end which is spaced from the anode-portion of the device, means for heating the inside of said re-entrant cathode-portion, cathode-fins disposed in good thermal and electrical conducting-relation to said re-entrant cathode-portion, a quantity of a vaporizable discharge-metal disposed near the junction of said re-entrant portion with the end-wall of the cathode-portion of the enclosure-means whereby said discharge-metal is vaporized by the heat of said re-entrant portion, said discharge-metal being selected from the group comprising cesium, rubidium and potassium, means for providing a vapor-duct from said quantity of vaporizable discharge-metal to the inner end of said re-entrant cathode-portion, and means disposed at the exit-end of said vapor-duct for providing an ejector for causing a greater vapor-pressure in the space occupied by the cathode-fins than in the space near the anode end of the device.

15. A vapor-electric device having an evacuated enclosure-means including a metal anode-portion of the enclosure-means at the top of the device, a metal cathode-portion of the enclosure-means at the bottom of the device, and an insulating sealing-means between said anode and cathode portions, the end-wall of said cathode-portion of the enclosure-means including a metal tubular re-entrant cathode-portion having a closed inner end which is spaced from the anode-portion of the device, means for heating the inside of said re-entrant cathode-portion, a hot-cathode element having a tubular hot-cathode member surrounding said re-entrant cathode-portion in heat-exchanging relation thereto, the outside of said tubular hot-cathode member carrying cathode-fins in good thermal and electrical contact therewith, a quantity of a vaporizable discharge-metal disposed near the junction of said re-entrant portion with the end-wall of the cathode-portion of the enclosure-means whereby said discharge-metal is vaporized by the heat of said re-entrant portion, said discharge-metal being selected from the group comprising cesium, rubidium and potassium, means for providing a vapor-duct from said quantity of vaporizable discharge-metal to the inner ends of said tubular re-entrant cathode-portion and said tubular hot-cathode member between said two tubular cathode-parts, and means disposed at the exit-end of said vapor-duct for providing an ejector for causing a greater vapor-pressure in the space occupied by the cathode-fins than in the space near the anode end of the device.

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No references cited.