June 17, 1952 J. L. BOYER 2,600,390

LOW-CAPACITY VAPOR-ELECTRIC DEVICE

Filed Dec. 20, 1950

Fig.1.

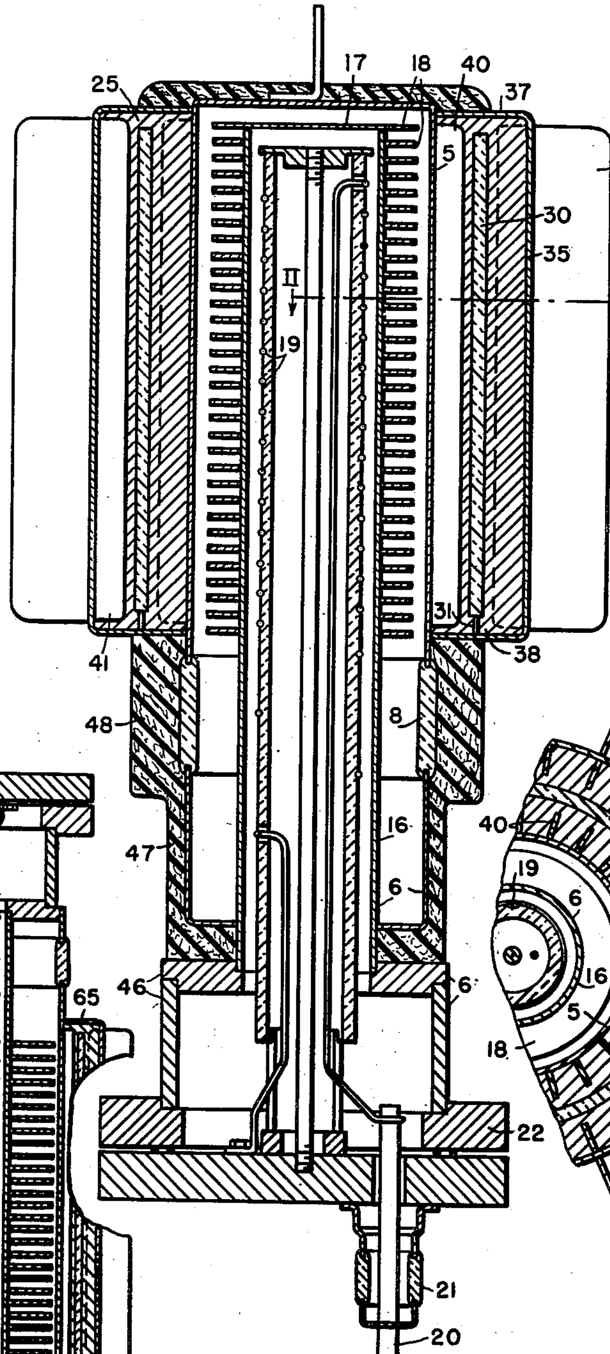
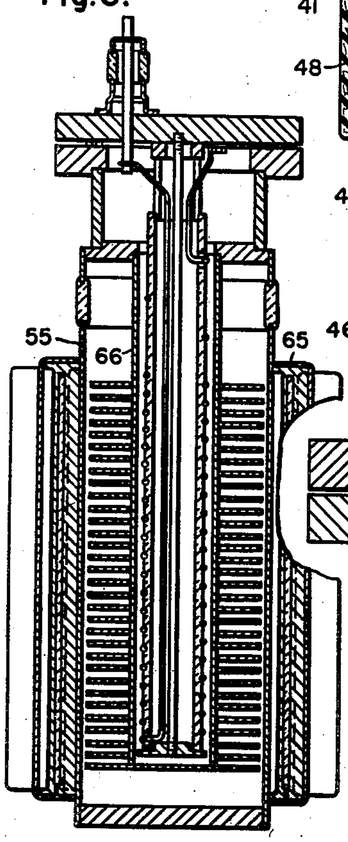


Fig.3.



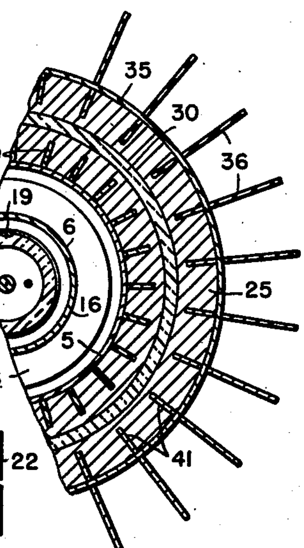


Fig.2.

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LOW-CAPACITY VAPOR-ELECTRIC DEVICE

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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 low-arc-drop hot-cathode arc-discharge devices using a vaporizable discharge-metal selected from the group consisting of cesium, rubidium and potassium. Such tubes have to be operated with a narrow range of temperatures on both the anode and the cathode, thus making it difficult to have an economical design for small tubes of this class.

An object of my present invention is to provide a tube of the stated class, which does not require any complicated temperature-control. In the accomplishment of this object, I provide, among other things, a cooling-means which includes a fusible material having a melting-point at approximately the desired temperature to which said cooling-means is to hold its associated internal portion of the device.

My invention is an improvement over a vapor-electric device which is described and claimed in a copending application of August P. Colaiaco and myself, Serial No. 144,354, filed February 15, 1950. As pointed out in this copending application, the three metals, cesium, rubidium and potassium, form a more or less distinctive class by themselves, which may be described as the alkali metals having four, five and six shells in their atomic structure, or the stable alkali metals having more than three shells. The entire group of alkali metals consists of six elements, of which the first two and the last are readily distinguishable from the other three, with which my invention is particularly concerned.

The two lightest alkali metals, lithium (Li) and sodium (Na) are separated, in some periodic tables, from the heavier light metals of the alkali-metal group (IA), as being distinctive because of their electron-grouping. The physical and chemical characteristics of these two lightest alkali-metals are also distinctively different from the group comprising cesium, rubidium and potassium. Sodium has a minimum breakdown voltage which comes at too low a pressure-distance product *pd* for my purposes; and it is also too active, chemically. Lithium has a vapor-pressure which is much too low for my purposes, as this low vapor-pressure requires too high a temperature to obtain a practically usable vapor-pressure which is high enough to give a sufficiently high current-density to be practical for my purposes.

The sixth and heaviest alkali metal, No. 87 in the periodic table, was formerly called virginium, but has now been proved to be an element which is called francium (Fa), an unstable

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atomic-pile product which is very radio-active, and which has an extremely short half-life of only a few minutes, so that is is unsuitable for my purposes.

It is also an object of my invention to provide a new tube-design in which the cesium or other discharge-metal is condensed on the cold end of the cathode, as distinguished from being condensed elsewhere, as on the anode, as in certain previous designs. This condensation-place of the discharge-metal is determined by making the cold end of the cathode the coolest part of the tube. This has the double advantage of getting the discharge-metal pool at the cathode-potential, in a place which makes it impossible to have positive-ion bombardment during the inverse voltage-periods, thus guarding against electron-emission from this pool and consequent arc-backs during said inverse voltage-periods. The discharge-metal pool, at the cold end of the cathode, is also at a spot at which the temperature is not materially affected by the intensity of the arc, and hence not materially affected by the load-current, as in previous tube-designs in which the discharge-metal pool was at or near a part of the anode.

My invention consists in the combinations, systems, structures, parts, and methods of design and operation, hereinafter described and claimed, and illustrated in the accompanying drawing, wherein:

Fig. 1 is a vertical longitudinal sectional view of an illustrative vapor-electric device embodying my invention in a preferred form.

Fig. 2 is a horizontal sectional view of the right half of the device shown in Fig. 1, as seen on a section-plane indicated by the line II—II in Fig. 1, and

Fig. 3 is a vertical sectional view of another illustrative form of embodiment of my device.

The form of embodiment of my invention, as shown in Fig. 1, comprises an evacuated enclosure-means including an anode-portion 5 of the enclosure-means, a cathode-portion 6 of the enclosure-means, and an insulator-to-metal sealing-means 8 between said anode and cathode portions. There is also enclosed, within the enclosure-means, a quantity of a discharge-metal selected from the group comprising cesium, rubidium and potassium.

The cathode-portion 6 of the enclosure-means includes a re-entrant metal tube-portion 16, which extends into the enclosure-means. This cathode-tube 16 has a closed inner end 17. The inner end of the cathode-tube 16 carries peripheral metal fins 18, extending out radially therefrom, like a plurality of washers, for providing an extended cathode-surface which constitutes the active arc-terminating surface of the cathode.

The cathode-tube 16 and its fins 18 are preferably made of nickel, or at least the exposed surfaces of these parts, which are exposed to the vapors within the device, are preferably made of nickel. The rest of the cathode-portion 6, and all of the anode-portion 5, may be made of either iron (including steel) or nickel.

The active part of the cathode, namely the cathode-tube portion carrying the fins 18, has to be heated to a suitable emitting-temperature during the operation of the device. When cesium is the discharge-metal, this cathode emitting-temperature is around 700° C. or 750° C., or even somewhat higher; when rubidium is at the emitting-temperature, the active cathode-portion should be maintained at a temperature of about 700 or 720° C. to say 800° C.; and when potassium is the discharge-metal, the active cathode-temperature should be perhaps about 800° C. to 900° C.

To heat the active emitting-surface of the cathode, I provide a cathode-heater 19, which is disposed within the cathode-tube 16, the heater being preferably concentrated at the finned end of the cathode-tube, and being supplied with a sufficient amount of electrical energy to maintain the desired temperature. The heater 19 may be supplied with electrical heating-energy through a terminal-lead 20 which extends through an insulating seal 21 in the base 22 of the cathode-portion 6.

In vapor-electric devices of the class described, it is necessary to maintain some internal portion of the device at a temperature which is cooler than any other internal portion of the device during the operation of the device, so as to provide a condensation-surface on which vapor of the discharge-metal condenses. The temperature of this condensation-surface determines the operating vapor-pressure of the discharge-metal, and hence it is necessary to provide a condensation-temperature which is within certain suitable temperature-ranges, being about 220° C. for cesium, 240° C. for rubidium, or 280° C. for potassium, these temperatures being merely illustrative. All other internal portions, both metals and insulators, of the device (other than said condensation-surface) have to be maintained at temperatures which are higher than the condensation-temperature, in order to prevent unwanted condensation.

In vapor-electric devices of the described class, it is also necessary to variably cool the anode. The play of the arc on the anode tends to heat the anode to temperatures which, is unchecked, would be hot enough to make the anode emit like a cathode, thus spoiling the operativeness of the tube. This anode-heating is a variable quantity, depending upon the intensity of the arc, and hence upon the amount of load-current which is being carried by the vapor-electric device. It is usually desirable to keep the anode at a fairly uniform low temperature, in order to keep well under the electron-emitting or backfiring-temperature of the anode.

In those discharge-tubes in which the condensation-surface is the anode, or a part of the anode, as will be described in connection with Fig. 3, the anode-temperature may be the condensation-temperature. In those types of tube in which the condensation-surface is provided at some part of the tube other than the anode, as will be described in connection with Fig. 1, it is necessary to hold the anode to some temperature which is higher than the condensation-temperature. When cesium is the discharge-metal, for example, in Fig. 1, the anode-temperature may be 232° C., or somewhere between 230 and 300° C.

In Fig. 1, I show a preferred form of embodiment of my device, in which a non-linear cooling-means is provided for the anode-portion 5, for automatically providing approximately the amount of cooling which is necessary to hold the anode at a fairly steady temperature. This non-linear anode-cooling means, for the tube which is shown in Figs. 1 and 2, is characterized by having a fusible material 25, which has a melting-point at approximately the desired temperature to which said cooling-means holds its associated internal portion of the device, in this case the anode-portion 5. When no portion of the anode-surface is the condensation-surface, as in the tube illustrated in Fig. 1, and when cesium is the discharge-metal, the fusible material 25 may be tin, which melts at 232° C., or it may be some metal alloy, or even an insulating compound, which has a melting-point between, say 230 and 300° C.

In the preferred form of construction of the fusible-material cooling-means, provision is made for the natural thermally induced circulation of the fusible material 25 after it has melted. To this end, I preferably design the device so that the heat-radiating enclosure-portion of the device, which is to be cooled, stands upright or in a vertical position, as is the case of the tubular side-walls of the anode-portion 5 of the device. Spaced from the outer surface of this heat-radiating enclosure-portion (such as the tubular anode-surface 5), I provide an upstanding heat-barrier 30, which is suitable heat-insulating solid. When the heat-radiating enclosure-portion, such as 5, is tubular or cylindrical, the heat-barrier 30 is also tubular or cylindrical, being mounted on suitable pins or feet 31. Spaced from the other side of the heat-barrier 30, I provide an upstanding heat-radiating cooling-plate 35, which, if the heat-barrier 30 is cylindrical, would also be cylindrical. The heat-radiating cooling-plate 35 radiates or conducts heat directly to the ambient atmosphere, either with or without the aid of heat-radiating fins 36.

The space between the heat-radiating enclosure-portion, such as the anode-portion 5, and the cooling-plate 35, is filled with the fusible material 25. For holding the fusible material 25 when it is melted, I provide a suitable container-means, such as is provided by top and bottom flanges 37 and 38 of the cooling-plate 35. The top and bottom ends of the heat-barrier 30 are spaced from the top and bottom portions 37 and 38 of this container-means, so that the molten fusible material 25 can circulate over the top of the heat-barrier 30 and under the bottom of the heat-barrier; or other suitable disposition and arrangement of the barrier is made so that such a circulation will be possible.

In the operation of the fusible-material cooling-means just described, the presence of the heat-barrier 30 prevents the conduction or radiation of very much heat from the anode-portion 5 of the evacuated container, as long as the fusible material 25 remains in its solid state, in which it does not circulate. As soon as the anode-surface reaches the melting-point of the fusible material 25, however, the anode begins to melt the fusible material, and the latent heat of fusion of the fusible material holds the anode to substantially the melting-point of this material, until substantially all of the fusible material is melted. When this happens, the fusible material begins to circulate, with a natural circulation, due to the fact that one side of the body of molten material is heated and the other side is cooled; and in this manner the circulating material carries heat away from the anode 5, and delivers it to the cooling-plate 35. This convection-current heat-transfer from the outer surface of the anode 5 to the inner surface of the cooling-plate 35 may be assisted, if desirable, by providing heat-transfer fins 40 on the outer surface of the anode 5, and other heat-transfer fins 41 on the inner surface of the cooling-plate 35.

In the preferred illustrative form of construction of a vapor-electric device, as shown in Fig. 1, I preferably make use of a special cathode-construction in which the active emitting inner end of the cathode-tube 16 is heated (by the heater 19), and in which suitable means are provided for externally cooling the outer, or enclosure-entering, end of the cathode-tube 16. The cathode-tube 16 is made long enough (and the tube-walls are thin enough) so that the bottom end, or enclosure-entering end, of this cathode-tube 16, or of the attached external cathode-parts, is the coolest part of the device, whereby the discharge metal condenses thereon. Usually, as illustrated, the natural heat-radiation from the exposed cathode-surfaces 46 to the ambient atmosphere, without any cooling-fins or external blowing-means, suffices to keep the attached end of the cathode-tube 16 at a uniform temperature which is just about right. Sometimes, it may be necessary to add a certain amount of heat-insulation 47, for keeping the cathode-portion 6 of the evacuated container from getting too cool, and this heat-insulation may be thickened, as indicated at 48, at places where the internal tube-parts are to be kept at still hotter, or non-condensation, temperatures, as in the vicinity of the insulator-part 8.

It will thus be observed that I have provided, in Fig. 1, a basic design in which the discharge-metal condenses on a surface which is not subject to variable amounts of heating in response to variable load-currents carried by the device. The cool bottom or outer end of the cathode-tube 16 is admirably suited for this purpose, because the hot inner end of this cathode tube necessarily operates at a fairly constant emitting-temperature, and the cool bottom or outer end of this tube is sufficiently far removed from the arc so that it is not materially affected by the intensity of the arc, which is another way of saying that it is not materially affected by the amount of load-current which is being carried by the device. In a small, inexpensive discharge-tube, therefore, without complicated automatic temperature-controlling means, it is easy to design the tube so that the cool end of the cathode-tube 16 operates at a fairly constant temperature, independent of load-conditions. In Fig. 1, I have chosen this cool-end cathode-temperature as the coolest temperature of the device, or the temperature at which condensation takes place, and at which the vapor-pressure within the device is controlled.

Since this cooling or condensing-place for the alkali-metal "pool" (which may be only a few drops) is at the cold end of the cathode, this alkali-metal pool is at the cathode-potential, and hence it cannot have any positive-ion bombardment which, if it were present, would initiate electron-emission and cause faults during the tube-operation. The collection of the alkali-metal pool at the cold end of the cathode is further advantageous over previous constructions in which this pool has been collected at or near the lower end of the anode of the device, because the lower end of the cathode is inherently much the better place, since its temperature is not affected by the intensity of the arc, and hence it is not affected by the load-current of the device.

In accordance with the preferred form of embodiment of my invention, as shown in Fig. 1, I combine, with this cathode-tube construction having the condensation-surface at its lower or outer end, a fusible-material cooling-means for automatically taking care of the wide range of cooling-rates which are necessary to take care of the anode-cooling, under variable load-conditions.

I thus provide a small, compact vapor-discharge tube which has no external moving parts, either for artificially circulating a cooling-medium or for cooperating with thermally responsive devices.

As previously intimated, however, my present invention is not limited, in its use, to the preferred construction which is shown in Fig. 1, as the fusible-material cooling-means is of general application to any device having an internally heated part which is subject to a wide range of internal heating, under various operating-conditions of the device. In particular, in vapor-electric tubes using a discharge-metal of cesium, rubidium or potassium, it is frequently desirable to apply my fusible-material cooling-means to the anode-portion of the evacuated enclosure, whether or not said anode-portion constitutes a condensation-surface for the discharge-metal. My fusible-material cooling-means is also of general application to the maintenance of the condensation-temperature, within narrowly prescribed limits, regardless of whether the condensation-surface is a part of the anode-portion of the tube, or the cathode-portion of the tube, or some other separate portion of the tube.

I have accordingly shown, in Fig. 3, an alternative form of embodiment of my invention, in a vapor-electric device in which the anode-portion 55 is held at such a temperature that at least a part of this anode portion 55 is the coolest part of the device, so as to provide the condensation-surface. In Fig. 3, this anode-portion 55 is provided with a fusible-material cooling-means 65, having a melting-point at about the desired condensation-temperature which controls the vapor-pressure of the tube. The other parts of the tube, in Fig. 3, may be more or less similar to the construction which has already been described for Fig. 1, except that the proportions are different, so that the outer or enclosure-entering end of the cathode-tube 66 does not run as cool as the condensation-surface which is provided on the anode-portion 55.

While I have illustrated my invention in only two illustrative forms of embodiment, I wish it to be understood that many variations are possible, in the precise forms of embodiment. I desire 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 an anode-portion of the enclosure-means, a cathode-portion of the enclosure-means, and an insulator-to-metal sealing-means between said anode and cathode portions, a quantity of a discharge-metal selected from the group comprising cesium, rubidium and potassium, a heating-means for heating the active emitting-portion of the cathode, a coolest-surface cooling-means for cooling some internal portion of the device to a temperature which is cooler than any other internal portion of the device during the operation of the device, whereby to provide a condensation-surface for the discharge-metal and to control the operating vapor-pressure of the discharge-metal, and a non-condensing-surface cooling-means for cooling some other internal portion of the device to a somewhat warmer temperature during the operation of the device, whereby to prevent the condensation of said discharge-metal on said other internal portion; characterized by at least one of said cooling-means including a fusible material having a melting-point at approximately the desired temperature to which said cooling-means holds its associated internal portion of the device.

2. The invention is defined in claim 1, characterized by said fusible-material cooling-means comprising the combination, with an upstanding heat-conducting enclosure-portion of the device, adjacent to the place which is to be internally cooled, of an upstanding heat-barrier spaced from the outer surface of said heat-conducting enclosure-portion, an upstanding heat-conducting cooling-plate spaced from the other side of said heat-barrier, said fusible material being disposed on both sides of said barrier and filling the space between said heat-conducting enclosure-portion and said cooling-plate, and a container-means for said fusible material when it is melted, the disposition and arrangement of the barrier and container-means being such that molten fusible material can circulate over the top of the barrier and under the bottom of the barrier.

3. A vapor-electric device having an evacuated enclosure-means including an anode-portion of the enclosure-means, a cathode-portion of the enclosure-means, and an insulator-to-metal sealing-means between said anode and cathode portions, a quantity of a discharge-metal selected from the group comprising cesium, rubidium and potassium, a heating-means for heating the active emitting-portion of the cathode, and an anode-cooling means including a fusible material having a melting-point at approximately the desired temperature to which said cooling-means holds said anode-portion of the enclosure-means.

4. The invention as defined in claim 3, characterized by said anode-cooling means comprising the combination, with an upstanding wall of said anode-portion, of an upstanding heat-barrier spaced from the outer surface of said upstanding wall, an upstanding heat-conducting cooling-plate spaced from the other side of said heat-barrier, said fusible material being disposed on both sides of said barrier and filling the space between said upstanding wall and said cooling-plate, and a container-means for said fusible material when it is melted, the disposition and arrangement of the barrier and container-means being such that molten fusible material can circulate over the top of the barrier and under the bottom of the barrier.

5. A vapor-electric device having an evacuated enclosure-means including an anode-portion of the enclosure-means, a cathode-portion of the enclosure-means, and an insulator-to-metal sealing-means between said anode and cathode portions, a quantity of a discharge-metal selected from the group comprising cesium, rubidium and potassium, a heating-means for heating the active emitting-portion of the cathode, a coolest-surface cooling-means for cooling some internal portion of the device, other than said anode-portion, to a temperature which is cooler than any other internal portion of the device during the operation of the device, whereby to provide a condensation-surface for the discharge-metal and to control the operating vapor-pressure of the discharge-metal, and a non-condensing-surface cooling-means for cooling said anode-portion to a somewhat warmer temperature during the operation of the device, whereby to prevent the condensation of said discharge-metal on said other internal portion; characterized by at least one of said cooling-means including a fusible material having a melting-point at approximately the desired temperature to which said cooling-means holds its associated internal portion of the device.

6. The invention as defined in claim 5, characterized by said fusible-material cooling-means comprising the combination, with an upstanding heat-radiating enclosure-portion of the device, adjacent to the place which is to be internally cooled, of an upstanding heat-barrier spaced from the outer surface of said heat-conducting enclosure-portion, an upstanding heat-conducting cooling-plate spaced from the other side of said heat-barrier, said fusible material being disposed on both sides of said barrier and filling the space between said heat-conducting enclosure-portion and said cooling-plate, and a container-means for said fusible material when it is melted, the disposition and arrangement of the barrier and container-means being such that molten fusible material can circulate over the top of the barrier and under the bottom of the barrier.

7. A vapor-electric device having an evacuated enclosure-means including an anode-portion of the enclosure-means, a cathode-portion of the enclosure-means, and an insulator-to-metal sealing-means between said anode and cathode portions, a quantity of a discharge-metal selected from the group comprising cesium, rubidium and potassium, a heating-means for heating the active emitting-portion of the cathode, and a coolest-surface cooling-means for cooling said anode-portion to a temperature which is cooler than any other internal portion of the device during the operation of the device, whereby to provide a condensation-surface for the discharge-metal and to control the operating vapor-pressure of the discharge-metal; characterized by said cooling-means including a fusible material having a melting-point at approximately the desired temperature to which said cooling-means holds said anode-portion of the enclosure-means.

8. The invention as defined in claim 7, characterized by said anode-cooling means comprising the combination, with an upstanding wall of said anode-portion, of an upstanding heat-barrier spaced from the outer surface of said upstanding wall, an upstanding heat-conducting cooling-plate spaced from the other side of said heat-

barrier, said fusible material being disposed on both sides of said barrier and filling the space between said upstanding wall and said cooling-plate, and a container-means for said fusible material when it is melted, the disposition and arrangement of the barrier and container-means being such that molten fusible material can circulate over the top of the barrier and under the bottom of the barrier.

9. A vapor-electric device comprising an enclosure-means, an anode, a cathode, and a quantity of a discharge-metal within said device, said discharge-metal being selected from the group consisting of cesium, rubidium and potassium; said cathode including a re-entrant metal tube-portion extending into said enclosure-means, said cathode-tube having a closed inner end, metal fins carried by said cathode-tube near said closed inner end, a cathode-heater disposed within said cathode tube, said cathode-heater being concentrated at the finned end of the cathode-tube, and means for cooling the enclosure-entering end of the cathode-tube, said cathode-tube being long enough so that its enclosure-entering end is the coolest part of the device, whereby the discharge-metal condenses thereon.

10. A vapor-electric device comprising an enclosure-means, an anode-portion of the enclosure-means, a cathode, and a quantity of a discharge-metal within said device, said discharge-metal being selected from the group consisting of cesium, rubidium and potassium; said cathode including a re-entrant metal tube-portion extending into said enclosure-means, said cathode-tube having a closed inner end, metal fins carried by said cathode-tube near said closed inner end, a cathode-heater disposed within said cathode tube, said cathode-heater being concentrated at the finned end of the cathode-tube, and means for cooling the enclosure-entering end of the cathode-tube, said cathode-tube being long enough so that its enclosure-entering end is the coolest part of the device, whereby the discharge-metal condenses thereon; and an anode-cooling means including a fusible material having a melting-point at approximately the desired temperature to which said cooling-means holds said anode-portion of the enclosing-means.

11. The invention as defined in claim 10, characterized by said anode-cooling means comprising the combination, with an upstanding wall of said anode-portion, of an upstanding heat-barrier spaced from the outer surface of said upstanding wall, an upstanding heat-radiating cooling-plate spaced from the other side of said heat-barrier, said fusible material being disposed on both sides of said barrier and filling the space between said upstanding wall and said cooling-plate, and a container-means for said fusible material when it is melted, the disposition and arrangement of the barrier and container-means being such that molten fusible material can circulate over the top of the barrier and under the bottom of the barrier.

12. A device having an internally heated part, an upstanding heat-radiating portion of the device for cooling said internally heated part, said heat-radiating portion having an upstanding outer surface, an upstanding heat-barrier spaced from the outer surface of said heat-radiating portion, an upstanding heat-radiating cooling-plate spaced from the other side of said heat-barrier, fusible material disposed on both sides of said barrier and filling the space between said heat-radiating portion and said cooling-plate, and a container-means for said fusible material when it is melted, the disposition and arrangement of the barrier and container-means being such that molten fusible material can circulate over the top of the barrier and under the bottom of the barrier, said fusible material having a melting-point at approximately the desired temperature to which said heat-conducting portion is to be held.

13. A vapor-electric device comprising an enclosure-means, an anode, a cathode, and a quantity of a discharge-metal within said device, said discharge-metal being selected from the group consisting of cesium, rubidium and potassium; said cathode including a metal tube-portion extending interiorly into said enclosure-means, a portion of said cathode-tube carrying metal fins at a region within the interior of the enclosure-means, means for heating the inside of the cathode-tube at the finned portion thereof, and means for cooling the cathode-tube in a region where it enters the enclosure-means, said cathode-tube being long enough so that said cooled enclosure-entering region is the coolest part of the device, whereby the discharge-metal condenses thereon.

14. A vapor-electric device comprising an enclosure-means, an anode-portion of the enclosure-means, a cathode, and a quantity of a discharge-metal within said device, said discharge-metal being selected from the group consisting of cesium, rubidium and potassium; said cathode including a metal tube-portion extending interiorly into said enclosure-means, a portion of said cathode-tube carrying metal fins at a region within the interior of the enclosure-means, means for heating the inside of the cathode-tube at the finned portion thereof, and means for cooling the cathode-tube in a region where it enters the enclosure-means, said cathode-tube being long enough so that said cooled enclosure-entering region is the coolest part of the device, whereby the discharge-metal condenses thereon; and an anode-cooling means including a fusible material having a melting-point at approximately the desired temperature to which said cooling-means holds said anode-portion of the enclosing-means.

15. The invention as defined in claim 14, characterized by said anode-cooling means comprising the combination, with an upstanding wall of said anode-portion, of an upstanding heat-barrier spaced from the outer surface of said upstanding wall, an upstanding heat-radiating cooling-plate spaced from the other side of said heat-barrier, said fusible material being disposed on both sides of said barrier and filling the space between said upstanding wall and said cooling-plate, and a container-means for said fusible material when it is melted, the disposition and arrangement of the barrier and container-means being such that molten fusible material can circulate over the top of the barrier and under the bottom of the barrier.

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No references cited.