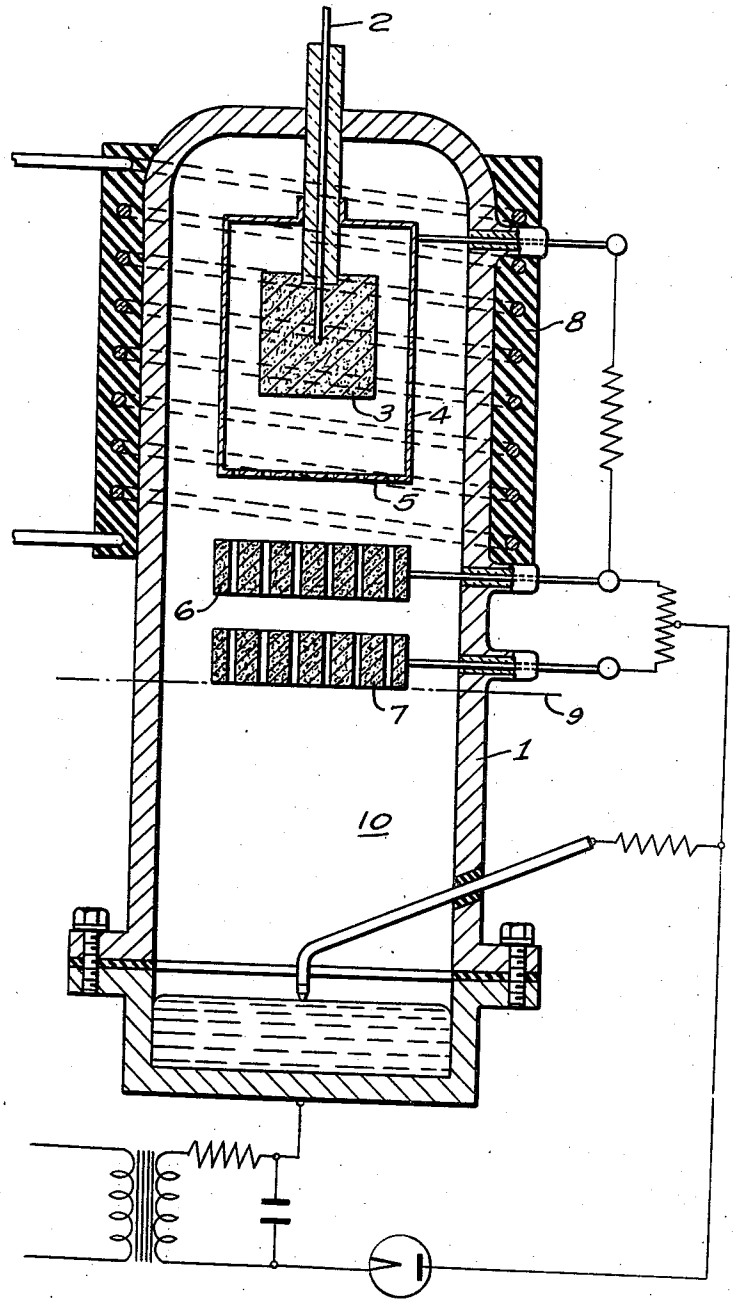
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VAPOR ELECTRIC DEVICE

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VAPOR ELECTRIC DEVICE

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My invention relates to a vapor electric device and particularly to an arc discharge device for operating at high voltages.

In the operation of arc discharge devices at high potential, it is well known that it is quite difficult to prevent such a discharge device from arcing back during the impermeable half-cycles. Many attempts have been made to avoid this difficulty. In arc converters for voltages up to 10–20 kv. relatively simple electrode arrangements will give satisfactory results. Much more complicated arrangements are required, however, when these apparatus must operate at voltages from a few up to many times 10,000 volts. It has been proposed, for instance, to subdivide in the latter case the arc path into sections by means of a plurality of intermediary electrodes to which are applied definite potential—ranging between the anode and the cathode potential, thus replacing the single gaseous discharge path that would have to take up very high voltage gradients by a plurality of series-connected discharge paths in which the voltage gradients will be relatively low. With such an arrangement, the discharge is controlled either by means of one single control grid, located near the cathode of the electrode system, or by means of a plurality of control grids, located between the intermediary electrodes that subdivide the potential difference between the anode and the cathode into a plurality of steps.

But many difficulties are encountered when one resorts to the use of a known arrangement of the kind just referred to. The fact that many high-voltage electrodes must be inserted between the cathode and the anode makes it more difficult to properly design such a discharge vessel, especially because the lead-in wires for the intermediary electrodes must usually pass through vacuum-tight seals located in a side-wall of the vessel. Furthermore, insofar as the arrangement of the connections is concerned, and also from the standpoint of the erection engineer, many obstacles are encountered on account of the large number of potential-steps involved. And sometimes it is difficult to make the firing system function properly, for instance, on account of the complicacy of the field distribution, so that in general it will be desirable to use only a few instead of a large number of intermediary electrodes between the cathode and the anode.

Application of the present invention will make it feasible to use the more desirable electrode-arrangement just referred to. In fact, it has been found that by resorting to a skillful combination of various measures—some of them being already known to those skilled in the art, while the remaining ones are novel—it becomes feasible to manufacture an electric discharge vessel for very high voltages (from a few up to many times 10,000 volts) which, although comprising only a few electrodes and a rather simple ignition system, will be arc-back-proof to the greatest possible extent, in addition to being accurately controllable.

In accordance with the present invention, the anode (or each anode) of the discharge vessel is surrounded by a shield combined with a grid-like member that is placed across the discharge path, and this shielding arrangement is kept at a definite potential having a value comprised between the anode and the cathode potential. In addition, there are provided two or more grid-members of the tubular or stack type for controlling the discharge, these grid-members being located in front of the screened-off anode-space, and all distances between the various electrodes and shields, as well as all distances between these members of the electrode system and the wall of the vessel being made shorter than the critical breakdown-length of the gas or vapor pressure prevailing under operating conditions. Furthermore, means are provided for establishing and maintaining a high temperature gradient (temperature drop towards the cathode) in the space comprised between the end-surface member of the anode shield and the surface facing the cathode of the grid that is mounted nearest the cathode.

The functioning of a discharge vessel equipped with this new electrode arrangement can be more adequately explained by referring to the attached drawing in which the figure is a sectional elevation of a discharge device according to my invention.

In the exemplary embodiment according to the drawing, **1** designates the wall of the discharge vessel, or the wall of an arm of this vessel, which can be made of a metal or of an insulating material. The lead-in stem for the anode is designated by **2**; to this stem is attached the anode-body **3**. The anode is surrounded by a shield **4**, whose end-surface in front of the anode is formed by a grid-like member **5**. The distance between shield and anode is everywhere shorter than the corresponding critical breakdown-length at the gas or vapor pressure prevailing under operating conditions.

Opposite the end-surface **5** of the anode shield **4** is mounted a control grid **6**, beyond which is

located a second control grid 7. The distances between the adjacent members 5, 6 and 7, as well as the distances between the electrodes and the wall 1 of the vessel, are everywhere shorter than the critical distance as determined by the well-known Paschen's curve.

A heater coil 8 is wound on the outer wall-surface of the vessel. In the case of the example of application represented on the drawing, the turns of the heater coil are so distributed in the vertical sense that when one proceeds in the downward direction, towards the lower portion of the vessel, the temperature will drop, the temperature gradient which determines this drop having a quite considerable value down to the level marked by the dot-and-dash line 9. For instance, the conditions can be so chosen that in the vessel behind the anode the temperature will be 200–250° C. or higher (with this exception that near the top wall of the anode-arm, the temperature will be decreasing again). This same high temperature will prevail immediately in front of the anode, but from here on and down to the line 9, the temperature in the space in which the grids 6 and 7 are located will gradually drop. Below said line, the temperature will be rather uniform, having a value of 80° C., say. As pointed out before, it is quite essential to see to it that in the space comprised between the surface 5 and the line 9, the temperature will drop from its maximum value down to the value which it has in the space 10.

It has been found that in a discharge vessel of the kind just described, the probability of an occurrence of arc-back will be reduced to a quite considerable extent, while on the other hand proper ignition can be secured without any difficulty. The two control grids 6 and 7 are kept at low potentials, and it is advisable to initiate at the ignition instant a capacitor discharge through these grids.

In the operation of the device according to my invention, the shield 4 with its end-surface member 5 sub-divides the space inside the vessel into two portions; i. e., a high-voltage space surrounded by the shield-walls, and a low-voltage space in which the control grids 6 and 7 are located.

In order to make the discharge vessel arc-back-proof to the highest possible degree, measures must be taken to prevent positive ions from wandering towards the anode and, more in particular, enter said high-voltage space during the impermeable half cycle (that is, during the half cycles when the anode is negative). To this effect, several measures are taken in a discharge vessel designed in accordance with the present invention, measures which can make the discharge vessel arc-back-proof to the desired extent only when they are taken simultaneously and in combination.

In the first place, the two grids 6 and 7 (it is possible, of course, to equip the vessel not with two, but three or more grids) are grids of the tubular or stack type; this means that a major part of the charged particles will be lost at the walls of the tubular grids by diffusion, so that they cannot do any more harm. Furthermore, the distances between the two grids on the one hand and between the grid 6 and the surface of the grid-like member 5 on the other hand are so chosen that any charged particles which might succeed in flying through the grids would not have much opportunity to produce ionization in the spaces comprised between the electrodes. In fact, the distances between members forming the boundaries of space-portions within which prevailing differences in potential could give rise to an occurrence of discharges or to the formation of an ion-avalanche are made everywhere shorter than the critical distance given by Paschen's law. In other words, in the design of each individual electrode as well as in the dimensioning of the anode-space, every precaution has been taken that will be of assistance in the prevention of arc-back.

Also, a second measure is taken, which consists in establishing a temperature-gradient in the low-voltage space (i. e., in the space comprised between 5 and 9), for it is a quite surprising experimental fact that the probability of an occurrence of arc-back can be lowered quite considerably by establishing a temperature gradient exactly in the space just mentioned, while on the other hand it was found by experiment that in order to facilitate the ignition process and to make it at the same time highly reliable, the temperature gradient should be produced within said space only, so that at the level of the line 9 the temperature will become uniformly equal to the average temperature prevailing in the remainder 10 of the space enclosed by the vessel.

It is advisable to design the heater coil which must produce said temperature gradient—and whose turns can be non-uniformly distributed in the vertical sense if this should be of advantage—in such a manner that its turns not only will extend over the entire height of the low-voltage space, up from the grid that is nearest the cathode, but will also heat the remainder of the anode-space. When the heater for the low-voltage space has a non-uniform turn-distribution (i. e., a turn-distribution that changes in steps), its arrangement must be such that it will supply per unit time a relatively large quantity of heat to the region in the neighborhood of the anode, and a relatively small quantity of heat to the region in the neighborhood of the cathode.

The desired temperature gradient can also be established by skillfully designing in a special manner the walls of the discharge vessel, and further by the appropriate use of any available cooling agent. In many instances satisfactory results can be obtained by simply designing the heater coil in such a manner that it will cover the entire anode-space and reach almost down to the grid that is nearest the cathode. The best procedure will be to determine experimentally the location of the level to which the heater-coil turns have to extend in the downward direction in order that at the bottom-surface of the lowest grid, the temperature shall have dropped to a value substantially equal to the average temperature prevailing in space 10 of the vessel.

In applying the measures described in the foregoing, due consideration was given to their mutual relationship, so that they can all be applied simultaneously with gratifying results. If in one of the discharge vessels of known design, one should make the distances between adjacent electrodes about equal to the critical breakdown-length, these distances would be relatively short, so that in general a large number of electrodes would have to be provided in order to make the vessel arc-back-proof to the desired extent. And it would not be feasible to place the electrodes at greater distances from one another, for when the distances between adjacent electrodes are too great, ion-avalanches could readily develop in the space-compartments bounded by the electrodes,

and these ion-avalanches could in turn initiate discharges in the impermeable direction. But in a vessel designed in accordance with the present invention, the additional measure is taken of establishing a temperature gradient in the low-voltage space, and by virtue of the presence of this temperature gradient, it has become possible (as proved by experiment) to obtain satisfactory results—without departing from the practice of using the more advantageous electrode-distances—with only two, or, at the utmost, with only a few electrodes (control grids). In this connection, the fact that the grids are of the tubular or stack type, i. e., the fact that they have a certain depth in the direction of the discharge path, is a contributing factor. Insofar as the ignition is concerned, the most satisfactory results will be obtained, as stated before, with an impulse-ignition system. With such a system, the grids, to which a low potential (for instance, the potential of the cathode) is being applied, receive at the instant at which the vessel must fire a voltage-pulse which can be supplied, for instance, by a capacitor. It is found that with such an arrangement there is first initiated a discharge between the cathode and the grid that is nearest the cathode; however, the plasma produced by this discharge will reach the other electrodes so rapidly that the discharge along the entire path up to the anode will be established practically at the same instant. The ignition problem proper is not a difficult one, because of the smallness of the required number of intermediary electrodes. But nevertheless, it has been found to be of advantage in this respect to prevent the establishment of any appreciable temeprature gradient (temperature drop towards the cathode) in the space **10** below the boundary-line **9**.

The electrode-distances should be determined in accordance with the statements made concerning this point in the foregoing; the dimensions of the electrodes, however, are determined most advantageously on the basis of practical tests. An approximate figure for the height of the tubular or stack-type grids can be obtained by application of the following rule: The tubular or stack-type grids should preferably have a height equal to from 1/6 up to 1/3 of their diameter, and this should be equal to from twice up to several times the distance between adjacent grids.

I claim as my invention:

1. An electric discharge device comprising a container defining a discharge space, an anode in said space, a cathode spaced from said anode, an anode stem connected to said anode, said stem passing through the container wall, a shield about the anode, a grid-like end member in said shield, a plurality of control grids between said anode shield and said cathode, said grids being spaced from each other and from the side wall of the container a distance less than the critical breakdown distance at the pressure prevailing under operating conditions and means for maintaining a temperature gradient in the space between the end of the anode shield and the surface of the control grid nearest to the cathode.

2. Discharge vessel as per claim 1, characterized by the feature that in order to produce said temperature gradient, a heating device is provided surrounding a portion of the container defining a part of the anode space.

3. An electric discharge device comprising a container, a cathode in said container, an anode cooperating with said cathode, a shield substantially enclosing said anode, a plurality of control grids between the shield and the cathode, said grids being spaced from the shield, the container wall and each other a distance less than the critical breakdown distance at the pressure prevailing during normal operating conditions, a heating coil for maintaining a temperature gradient between the end of the shield and the grid surface nearest to the cathode, said heating coil covering the portion of the container adjacent the anode and at least a portion of the container between the anode and the grid surface nearest to the cathode.

4. Discharge vessel as per claim 3, characterized by the feature that the electrodes and the heating devices are so dimensioned that in the space behind the anode the temperature will amount to at least 200–250° C., while in the space between the cathode and the grid that is mounted nearest the cathode, the temperature will have a value between 70 and 90° C.

5. Discharge vessel as per claim 1, characterized by the feature that the grids mounted in front of the anode have a height equal to from one-third to one-sixth of their diameter.

6. A discharge vessel as per claim 1, characterized by the feature that at least one grid is used for controlling the discharge and is held at a low potential.

7. A discharge vessel as per claim 1, characterized by the feature that a capacitor is connected to the control grids for supplying a voltage impulse for firing purposes.

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