

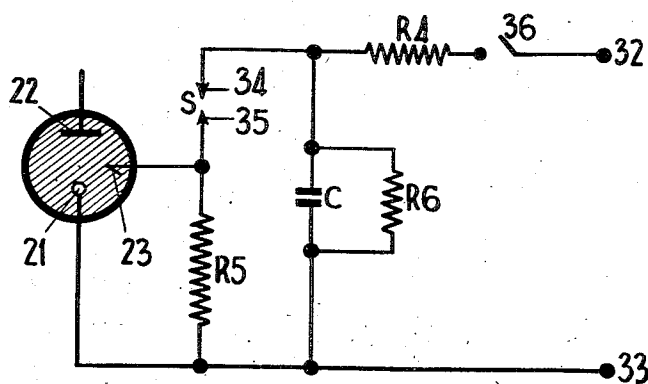
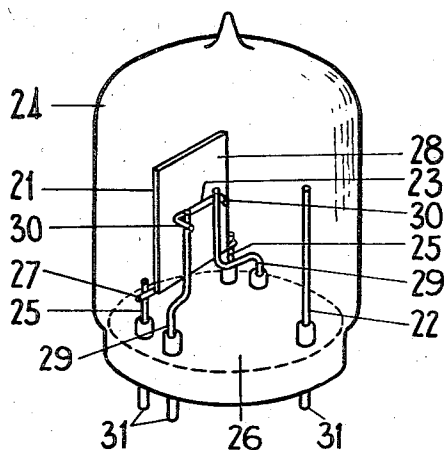
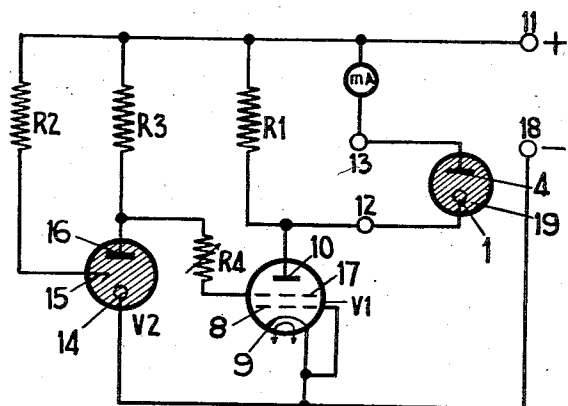
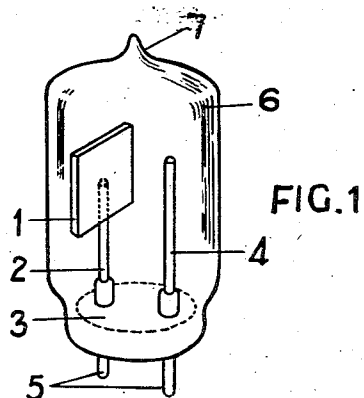
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MANUFACTURE OF COLD-CATHODE ELECTRIC DISCHARGE DEVICES

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MANUFACTURE OF COLD-CATHODE ELECTRIC DISCHARGE DEVICES 5

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5 Claims. (Cl. 316—26)

This invention relates to the manufacture of cold-cathode gas-filled electric discharge devices of the type wherein the cathode consists of a metal support carrying on at least one surface an electron emissive coating containing one or more metal oxides of lower work function than the metal of the support.

More particularly, though not exclusively, the invention relates to glow discharge devices of this type such as are employed in electrical communication systems, for example telephone circuits, for switching operations and the like.

The metal oxides most usually employed in devices of the type specified are the oxides of the alkaline earth metals, although other oxides, for example thorium, are sometimes used. In order that the oxide coatings may have a suitably low work function, it is necessary to activate them after they have been formed, that is to say to subject them to a treatment which will reduce some of the oxide to free metal, and one known way of effecting this electrically is to subject the coating to the action of a high frequency spark discharge applied between the anode and cathode of the device; this treatment has been effected with the device containing its normal gas filling and continued until the high frequency spark discharge playing over the oxide-coated surface of the cathode has activated the whole of the surface. It has been found, however, that the thickness of the oxide coatings that can be satisfactorily activated by this process is limited, usually to that corresponding to a coating weight of less than 1 milligram per square centimetre. The life of a device of the type specified depends, however, on the amount of activating material present, and hence on the thickness of the coating, and the object of this invention is to provide an electrical method of activating the oxide coating which is less subject to this limitation on the thickness of the coating.

The invention depends on a phenomenon which we have observed when a gas-filled discharge device having an unactivated oxide-coated cathode, and a filling pressure of only a few millimetres mercury, is operated with a unidirectional applied voltage between the cathode and anode and with the cathode negative with respect to the anode. As the voltage is increased from zero, a discharge through the device commences when the voltage reaches a certain critical value and is characterised by a bright spark which forms on the surface of the cathode and rapidly moves from point to point over the cathode surface. This condition of the discharge is, however, very unstable and usually the current either falls to a value at which an abnormal glow discharge forms on those parts of the cathode surface already activated or increases to a value where a stationary thermal arc appears between the anode and the cathode, depending on the particular circuit arrangement employed. We have now found that this spark condition of the discharge can be utilised for effecting a satisfactory activation of the whole of the oxide coating even with thicknesses corre-

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sponding to a coating weight in excess of 1 milligram per square centimetre.

According to the invention in the manufacture of an electric discharge device of the type specified the oxide coating of the cathode is activated by a method which comprises connecting the oxide-coated cathode to the negative terminal of a direct current supply, connecting another electrode of the device to the positive terminal of the supply, and passing an electric current between the cathode and said other electrode whilst the envelope of the device is filled with an ionisable gas filling at a low pressure, said current and pressure being such that there is obtained a highly mobile spark discharge which moves rapidly from point to point over the surface of the coating and activates the coating, the value of the discharge current being controlled during the activation process so as to lie between limits at which the discharge is maintained in said highly mobile spark condition until the activation of the coating by said method has been completed.

The limiting values of the current for the activating process will, of course, depend upon the electrode geometry and the actual gas filling employed, and may readily be determined by trial for any particular form of device as required.

We have found that the gas filling for the activating process preferably lies between 5 and 15 millimetres mercury, which is in general much lower than the final gas filling pressure of the device.

When the whole of the cathode coating has been activated by the method according to the invention, the highly mobile spark discharge condition ceases, and the discharge changes either into an abnormal glow condition or into a stationary arc condition, depending on the current and circuit arrangement used, and this change gives an indication that the activation process has been completed.

The effective resistance of a device of the type specified whose cathode is being activated in accordance with the invention will vary as the process proceeds, and the control of the current through the device within the required limits, so as to maintain the discharge in the highly mobile spark condition, may either be controlled manually, for example by means of a variable resistance in series with the device, or automatically, as desired.

For controlling the current automatically the device may be connected in series with a pentode-like thermionic valve, that is to say a valve which can be arranged to operate on a substantially flat part of an anode current/anode-cathode voltage characteristic such that over a considerable range of voltages applied between its anode and cathode, the anode current varies only slightly; some forms of tetrode as well as pentodes and valves having more than five electrodes are of this kind. The valve is arranged to operate on a flat part of its characteristic as aforesaid with the anode current adjusted so that the current through the device lies within the range of values required for the activating process to be carried out in accordance with the invention, the current through the device during the activating process being maintained at a substantially constant value (that is to say within a relatively small range of variation from a mean value, for example plus or minus 5 milliamps) within said limits despite changes in the effective resistance of the device and the corresponding changes in the anode-cathode voltage of the valve.

Thus the device may form part of the anode load of a tetrode valve the control grid and cathode of which are connected together, and the screen grid of which is arranged to be maintained at a potential relative to the cathode which is controllable for adjusting the anode current to a required value, the anode current being ad-

justed before the commencement of the activation process to a value which is held substantially constant throughout the process and which is such that during the process the discharge current through the device lies between said limits and is maintained substantially constant until the process is completed.

By employing a circuit arrangement such that when the oxide coating of the device has been completely activated the increase in effective resistance of the device results in the valve no longer operating within the said range of anode-cathode voltages within which there are only slight variations in the anode current, the decrease in current through the device, associated with transition to the abnormal glow regime, may be arranged to give a further indication that the activating process is completed, for example by the change in the reading of a milliammeter connected in series with the device.

The method of activation in accordance with the invention is especially suitable for activating cathode coatings consisting of one or more of the alkaline-earth metal oxides, and satisfactory activations of coatings of this kind having a coating weight of 3 milligrams per square centimetre have successfully been carried out.

Devices having a relatively long operating life can thereby be constructed by employing an activating process in accordance with the invention, such devices being especially suitable for use in apparatus which has to be operated for long periods with little or no attention, for example as switches in telephone circuits.

In devices in which the cathode coating consists of one or more of the alkaline earth metal oxides, the unactivated oxide coating has a white powdery appearance, but at every point of contact of the rapidly moving spark with the coating the colour of the coating changes to that of a very dark brown, the movement of the spark over the surface thus producing a series of dark specks which gradually spread to form a uniformly dark surface as the process proceeds, thereby giving a further indication when the process is completed.

If desired the activation process according to the invention, or primary process as it will hereinafter be referred to, may be followed by a secondary activation process for bringing the cathode coating of the device to an even higher state of activation than may be obtained by subjecting it to said primary process alone.

In this secondary process a series of short duration spark discharges, having peak currents of several amperes, are arranged to take place between the cathode and at least one other electrode of the device, with the cathode acting as the negative electrode, whilst the envelope of the device is filled with an ionisable gas filling at, or approximately at, the final gas filling pressure of the device.

This double activation process activates the oxide cathode coating to an even higher degree than does the primary activation process alone, and moreover is suitable for coatings having a coating weight of over 1 milligram per square centimeter, since the primary activation of the cathode fuses the material of the coating and renders it able to withstand the high current spark discharges of the secondary activation process.

The secondary activation process is preferably carried out after the envelope of the device has been sealed off, the series of spark discharges conveniently being produced by repeatedly discharging a condenser through the device, as in some known methods of cathode activation.

During the secondary activation process the appearance of alkaline earth oxide coatings (which are the coatings most commonly used) undergoes a change from a dull dark brown colour, resulting from the primary activation process, to a smooth shiny metallic appearance, the degree of activation effected being indicated by the amount of change produced in the colour of the coating. The duration of the process will depend on the extent to which the coating is required to be activated, and on the frequency and duration of the spark discharges, and may readily be

determined by trial for any particular form of device as required.

The method of activating the cathode in accordance with the invention may be employed to advantage in the manufacture of devices of the type specified having, in addition to the cathode and anode, a third electrode, more often referred to as the trigger electrode, located in line with and between them. Owing to the fact that the trigger electrode is usually situated only a relatively short distance from the coated surface of the cathode, the primary activation is preferably carried out by passing a controlled current between the anode and the cathode, thus enabling the activation to be effected over a larger area than if the controlled current were passed between the trigger electrode and the cathode. However in such a process part of the cathode surface is shielded from the anode by the trigger electrode, thereby resulting in the shielded part of the coating being activated to a lesser extent than the unshielded parts, and this is usually undesirable since, in order for the breakdown voltage between the trigger electrode and the cathode to have the smallest possible value for a given spacing between them and for a given gas filling, it is preferable for the cathode coating to have the highest degree of activation in the neighbourhood of the trigger electrode. By arranging that the spark discharges of the secondary activation process take place between the trigger electrode and the cathode the degree of activation of the shielded part of the coating is raised to that of the unshielded portions, and it, and the neighbouring regions of the coating, are then brought to an even higher state of activation as the process proceeds.

The method of activation according to the invention may also usefully be employed for activating the cathode of devices of the type specified having a trigger electrode located adjacent to an edge of the cathode, since by increasing the state of activation of the cathode coating in the region of the trigger electrode the auxiliary discharge between the cathode and the trigger electrode in operation of the device is less likely to form on the uncoated surface of the cathode.

The manufacture of two cold-cathode electric discharge devices of the type specified in accordance with the invention will now be described by way of example with reference to Figures 1 to 4 of the accompanying schematic drawings, in which—

Figure 1 represents a perspective view of a two electrode device,

Figure 2 shows a particular circuit arrangement which may be employed for automatically maintaining the discharge current through the device at a substantially constant value as the primary activation process is carried out,

Figure 3 represents a perspective view of a three electrode device, and

Figure 4 shows a particular circuit arrangement for carrying out the secondary activation process for the cathode of the device.

Thus referring to Figure 1 the cathode 1 of the device shown comprises a flat rectangular nickel sheet 10 millimetres long by 8 millimetres wide by 0.2 millimetre thick, on one surface of which is provided the electron emissive oxide coating consisting of a combination of barium, strontium and calcium oxides. To the other, uncoated, surface of the cathode is welded a nickel supporting wire 2, the wire being located centrally between the two longer edges of the cathode and projecting, parallel to said edges, beyond one of the shorter edges thereof, the outer end of the wire being sealed into a pressed glass disc 3, which constitutes the base of the device, with the coated surface of the cathode facing inwards towards the axis of the disc.

Also sealed into the disc 3 so that it extends perpendicularly therefrom in the same direction as the support wire 2 immediately opposite the centre of the coated sur-

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face of the cathode, is an additional nickel rod which constitutes the anode 4 of the device, the distance between the anode 4 and the cathode surface being 8 millimetres and the length of the anode being such that its free end is approximately level with the top end of the cathode 1.

The cathode support wire 2 and the anode 4 are continued within the disc 3 by lengths of copper-clad nickel wire for satisfactory sealing into the disc, and these lengths of wire are continued on the opposite side of the disc by nickel-iron-chromium rods 5 which are embedded at one end in the disc and constitute the terminal pins of the device.

The anode and cathode are enclosed within a substantially tubular glass discharge envelope 6 into one end of which is sealed, for example by drop sealing, the pressed glass disc 3, and which is closed at the other end by a tipped off pumping stem 7, the tube containing, after manufacture, a gas filling consisting of a mixture of, by volume, 80% neon and 20% argon at a total pressure of 40 millimetres of mercury.

During the manufacture of the device the nickel sheet which forms the cathode 1 is first welded to the nickel support wire 2, and is then washed in carbon tetrachloride followed by heating to a temperature of 1000° C. in an atmosphere of hydrogen for 15 minutes in order to cleanse the surface of the cathode and to remove surface grease.

The surface of the cathode to which the support wire 2 is welded, hereinafter referred to as the rear surface of the cathode, is then coated with aluminium paint in order to prevent glow discharges being formed on that part of the cathode in operation of the device, and the cathode is then reheated in an atmosphere of hydrogen to 925° C. for 15 minutes, there being a slight amount of oxygen present which is sufficient to oxidise the aluminium so as to form a sintered coating of aluminium oxide on that surface of the nickel.

The oxide coating, which consists of a combination of barium, strontium and calcium oxides, is formed on the front surface of the nickel sheet by spraying it in known manner with a suspension of the appropriate carbonates in a suitable binder to form a coating of 3.3 milligrams of the carbonate per square centimetre, the carbonate coating being decomposed after the cathode has been mounted within the device and whilst the envelope of the assembled device is connected to the exhausting pump, by means of eddy current heating to 1100° C. so as to form a triple oxide layer on the cathode.

The activation of the cathode coating using only the primary process in accordance with the invention will now be described. For this purpose the envelope of the device is filled with a mixture of, by volume, 80% neon and 20% argon at a pressure of 5 to 10 millimetres of mercury and a steady D. C. potential is applied between the cathode and the anode of the device, with the cathode connected to the negative terminal of the supply, of such a value and so controlled as to obtain a substantially constant arcing current of 100 milliamps between the anode and cathode, causing an intense bluish-white highly mobile spark to form on the cathode surface, the spark moving from point to point on the surface with great rapidity.

Before the activating process the triple oxide coating on the cathode has a white powdery appearance, but as the spark moves rapidly over the surface, at every point of contact the colour of the coating is transformed to a very dark brown, the random movement of the spark thus producing a series of very dark specks which spread over the surface as the operation proceeds, until the entire coating has a uniformly dark brown appearance and none of the original white oxide remains. The activation of the cathode coating by the mobile spark process is then complete, the time taken from the commencement of the sparking process to its completion being of the

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order of one minute for a device substantially as described.

For ageing the device the envelope is then re-evacuated and filled with a mixture of, by volume, 80% neon and 20% argon at a pressure of 10 millimetres of mercury, and a direct current of 20 milliamps passed between the anode and cathode, with the cathode as the negative electrode, for five minutes. The pressure of the gas filling is then increased to 25 millimetres of mercury and the current is stepped up to 30 milliamps for another five minutes, the gas pressure finally being increased to 40 millimetres of mercury and a current of 40 milliamps being passed for a further period of five minutes.

The envelope of the device with the gas filling consisting of, by volume, 80% neon and 20% argon at a total pressure of 40 millimetres of mercury is then sealed off, the ageing process then being completed by over-running with a current of 30 milliamps for several hours.

To maintain the current through the device automatically at the required value during the activating process a circuit arrangement as shown in Figure 2 is employed. In this arrangement there is included a tetrode valve V1, the control grid 8 and the indirectly heated cathode 9 of which are connected to earth, and the anode 10 of which is connected through a resistor R1 to the positive supply terminal 11 of a D. C. supply of 250 volts, the negative terminal 18 of the supply being earthed.

The anode 10 of the valve V1 is also connected to one contact terminal 12 to which the cathode 1 of the cold cathode discharge device 19 is arranged to be connected during the activating process, another contact terminal 13, to which the anode 4 of the discharge device is arranged to be connected, being connected to the positive D. C. supply terminal 11 through a milliammeter mA.

A gas-filled voltage stabilising valve V2 has its cathode 14 connected to earth and its control electrode 15 connected to the positive D. C. supply terminal 11 through a resistor R2, the anode 16 being connected to the positive supply terminal through a resistor R3, and to the screen grid 17 of the valve V1 through an adjustable resistor R4 for supplying an adjustable but stabilised voltage to the grid 17 for controlling the current through the valve V1.

The values of the circuit parameters are chosen so that with the device connected to the contact terminals 12, 13 as hereinbefore described the valve V1 operates substantially on the flat part of its anode current/anode-cathode voltage characteristic so that although there may be considerable changes in the value of the anode load, and thereby in the voltage drop across the load, the resulting variations in current through the valve and hence the load are extremely small.

For carrying out the activation process a dummy load resistance having a value approximately the same as the resistance of the discharge device whose cathode is to be activated is first connected between the contacts 12, 13 with the device left disconnected and the valve current adjusted to a value of 100 milliamps by means of the variable resistor R4. The dummy load resistance is then removed and replaced by the discharge device, the cathode 1 of the device being connected to the contact terminal 12 and the anode 4 of the device being connected to the contact 13. The activation of the cathode then proceeds, and is characterised by an intense bluish-white spark rapidly moving over the surface of the cathode 1 of the device as hereinbefore described, the valve V1 maintaining the current through the device at approximately 100 milliamps despite changes in the resistance of the tube as the cathode is activated. However when the activation process is complete the voltage drop across the device is such that the valve V1 no longer operates on the flat portion of its voltage/current characteristic and the current through the device drops considerably from

its original value, thereby giving an indication, in addition to the change in colour of the cathode coating of the device, that the activation process has been completed.

Such an indication may be desirable, for example, where the devices are being manufactured by mass-production methods in order to ensure that the cathode of each device is completely activated and also to reduce the possibility of a device being seriously over-run when the activation process has been completed, which latter might result in a substantial reduction in the operational life of the device.

Typical circuit components for maintaining a current of 100 milliamps through a discharge device constructed as described by way of example are as follows:

Tetrode valve V1.....	CV 1075.
Voltage stabilising valve V2....	CV 395.
Resistor R1.....	0.1 megohm.
Resistor R2.....	0.1 megohm.
Resistor R3.....	1500 ohms.
Resistor R4.....	Maximum value 22,000 ohms.

For a device as described the current during the activation process should lie between a minimum value of approximately 75 milliamps (below which the mobile bluish-white spark discharge will be replaced by an abnormal glow discharge on the parts of the cathode coating which have already been activated) and a maximum value of about 120 milliamps (above which the discharge will change into a stationary arc discharge having a red-dish colour instead of the bluish-white colour of the rapidly moving spark discharge). By arranging that the discharge current lies in the region of 100 milliamps any variations either side of this figure which might occur within these limits will not result in the interruption of the activating process.

For devices comprising a cathode of a different size or configuration, or different gas filling, the above limits will, of course, vary from those given above and may easily be obtained by trial.

The cold cathode device shown in Figure 3 consists of a cathode 21, an anode 22 and, located between and in line with the anode and cathode, a trigger electrode 23, the electrodes being mounted within a glass envelope 24 filled with an ionisable gas.

The cathode 21 consists of a flat rectangular nickel sheet approximately 10 millimetres long by 8 millimetres wide by 0.2 millimetre thick, carried by two support wires 25 which are sealed at their opposite ends into a pressed glass disc 26 which constitutes the base of the device. For supporting the cathode the two support wires 25 are welded to opposite ends of a nickel mounting wire 27 which is itself welded to the uncoated surface of the cathode along one of the shorter edges thereof, the ends of the wire, to which the support wires are welded, projecting slightly beyond the cathode, and the cathode is mounted with its plane perpendicular to the glass disc 26 and with its coated surface 28 facing inwards towards the disc axis.

The anode 22 consists of a straight nickel wire itself sealed at one end into the glass disc 26 so that it projects perpendicularly therefrom and positioned so that it is immediately opposite the centre of the coated surface 28 of the cathode 21, the anode-cathode spacing being 8 millimetres. The trigger electrode 23 also consists of a length of nickel wire 0.5 millimetre in diameter and about 8 millimetres long, the centre part of which lies parallel to the cathode and the glass disc 26, and the two ends being bent at right angles away from the cathode so that they extend perpendicularly thereto. The spacing of the said centre part of the trigger electrode 23, which is approximately 4 millimetres in length, is 0.3 millimetre from the surface of the cathode, and it is mounted, with its centre point immediately opposite the centre of the cathode, by means of two support wires 29 which are each sealed at one end into the pressed glass disc 26 and are spot welded

at their opposite ends to the bent ends 30 of the trigger electrode 23.

The cathode and trigger electrode support wires 25 and 29 respectively, and the anode wire 22 are continued within the glass disc 26 by lengths of copper-clad nickel wire for satisfactory sealing into the disc, and these lengths of wire are continued on the opposite side of the disc by nickel-iron-chromium rods 31 which are embedded at one end in the disc and which constitute the terminal pins of the device.

The ionisable gas filling of the device consists, after sealing off, of a mixture, by volume, of 75% neon and 25% argon at a total pressure of 40 millimetres of mercury.

During the manufacture of the device the nickel sheet which forms the cathode 21 is first welded to the mounting wire 27 and is then cleaned in a similar manner to the cathode of the device shown in Figure 1, the cathode being similarly provided on the rear surface with a coating of aluminium paint and on the front surface with a coating of barium, strontium and calcium oxides, the latter coating being formed by decomposition of the appropriate carbonates as already described.

The oxide coating is then activated by the primary activation process, for which purpose the envelope is filled with a mixture, by volume, of 75% neon and 25% argon at a filling pressure of 5 to 10 millimetres of mercury, a steady D. C. potential is then applied between the cathode and the anode of the device, with the cathode negative with respect to the anode, of such a value as to obtain a steady arcing current which is controlled at a value of 100 milliamps, this arcing current causing an intense bluish-white highly mobile spark to form on the cathode surface and to move from point to point over the surface with great rapidity; for automatically controlling the current at the required value during this activation process the circuit arrangement described by way of example with reference to Figure 2 may conveniently be employed.

During this primary activation process the white triple oxide is gradually changed to a very dark brown colour as the spark moves rapidly over the cathode surface, and at the completion of the process substantially the whole of the coating, apart from the part of the coating shielded from the anode by the trigger electrode, has a uniformly dark brown appearance and none of the white oxide remains. The shielded part of the coating has a slightly lighter appearance showing that it has not been as fully activated in that region as the rest of the coating.

The envelope is then re-evacuated and filled with a mixture, by volume, of 75% neon and 25% argon at a filling pressure of 10 millimeters of mercury, a direct current of 20 milliamps being passed between the anode and cathode, with the cathode as the negative electrode, for five minutes. The pressure of the gas filling is then increased to 25 millimetres of mercury and the current is stepped up to 30 milliamps for another five minutes the gas pressure finally being increased to 40 millimetres of mercury and a current of 40 milliamps being passed for a further period of five minutes.

The envelope of the device with the gas filling consisting, by volume, of 75% neon and 25% argon, at a total filling pressure of 40 millimetres of mercury is then sealed off. The cathode is then subjected to the secondary activation process in accordance with the present invention, as will now be described.

One particular circuit arrangement for carrying out the secondary activation process is shown schematically in Figure 4 of the drawings. This circuit comprises a capacitor C connected in series with a resistor R4 across two input terminals 32, 33 which are arranged to be connected in operation to a direct current supply of 1500 volts, the resistor R4 being connected between the capacitor C and the positive input terminal 32. One electrode 34 of a spark gap S is connected to the junction of

the resistor R4 and capacitor C, and the other spark gap electrode 35 is connected through a resistor R5 to the opposite side of the capacitor C and to the cathode 21 of the discharge device. The trigger electrode 23 is connected directly to the spark gap electrode 35, and the anode 22 of the device is left disconnected. A bleeder resistor R6 having a very high resistance is shunted directly across the capacitor C in order to allow any charge on the capacitor to leak away after the process has been completed, and a switch 36 is connected in the positive lead between the positive input terminal 32 and the resistor R4.

On switching on, the voltage across the capacitor C rises as the capacitor charges, the voltage across the resistor R5, and hence between the trigger electrode 23 and the cathode 21 of the discharge device, remaining at zero whilst no discharge occurs between the spark gap electrodes. However when the voltage across the capacitor C reaches a value sufficient to cause a spark to pass across the said gap, substantially the whole of the voltage across the capacitor is applied across the resistor R5 and hence across the trigger-cathode gap of the device. This voltage is sufficient to cause a spark discharge to occur between the trigger electrode 23 and the cathode 21, and the capacitor discharges through the spark gap and the device. As the voltage across the capacitor drops below a certain value the discharge ceases, the resistance of the path through the spark gap and the device regain their original value and the capacitor commences to recharge, the operation then automatically being repeated. The charging and discharging of the capacitor occurs with great rapidity, the repetition rate and the amount of charge passing through the device in each cycle depending on the values of the circuit components employed and on the voltage of the D. C. supply.

After the secondary activation process has been carried out the device is finally aged by being over-run with a current of 30 milliamps between the anode and cathode for several hours.

For a device constructed as described by way of example, and with the spacing between the cathode and trigger electrode as stated, the following component values were found to be suitable for a circuit arrangement as shown in Figure 4:

Capictor	μf.	0.1
Resistor R4.....	ohms	470,000
Resistor R5.....	megohms	4.7
Resistor R6.....	do	10

Distance between spark gap electrodes 0.05-0.1 mm.

With such a circuit arrangement a satisfactory activation of the cathode is obtained by subjecting it to the spark discharges of the secondary activation process for a period of about 2 to 5 minutes.

The secondary activation process in accordance with the invention may also be used for activating the cathode in devices of the kind specified employing only a cathode and an anode, for example as shown in Figure 1, the spark discharges of the secondary activation process then being arranged to take place between the anode and the cathode, and the process may also be used in devices having one or more trigger electrodes which are not located in line with the cathode and anode. In one example of the latter kind of device the anode and cathode are formed substantially as in the device shown in Figure 3 of the present drawings, and the device is provided with two trigger electrodes, each consisting of a nickel wire arranged parallel to the anode, and located about 1 millimetre from opposite edges of the cathode, slightly nearer to the anode than the smooth continuation of the coated cathode surface but not in line with the anode and the cathode.

When activating the cathode of such a device by a secondary activation process employing a circuit arrangement substantially as shown in Figure 4 of the present

drawings both trigger electrodes are simultaneously connected to the junction of the spark gap electrode 35 and the resistor R5, and regions of the coating extending along the edges of the cathode adjacent to the trigger electrodes are subjected to the high current spark discharges for a period of about 2 to 5 minutes. The increased activation of the coating in this region reduces the possibility of the auxiliary discharges, produced between the trigger electrodes and the cathode in operation of the device, from forming on the rear surface of the cathode, even when the trigger electrodes are almost in alignment with the coated surface of the cathode.

It will be appreciated that the double activation process may also be used for activating the cathodes of devices of the type specified other than those hereinbefore particularly described; the values of the components used in the circuit arrangement employed for producing the spark discharges of the secondary activation process depend upon the electrode geometry of the device whose cathode is to be activated in any particular case, and may easily be obtained by calculation or trial.

I claim:

1. The manufacture of a cold-cathode gas-filled electric discharge device of the type in which the cathode consists of a metal support carrying on at least one surface an electron emissive coating containing one or more metal oxides of lower work function than the metal of the support, wherein the oxide coating of the cathode is activated by a method which comprises connecting the oxide-coated cathode to the negative terminal of a direct current supply, connecting another electrode of the device to the positive terminal of the supply, and passing an electric current between the cathode and said other electrode whilst the envelope of the device is filled with an ionisable gas filling at a pressure below the final gas filling pressure of the device, said current and pressure being such that there is obtained a highly mobile spark discharge which moves rapidly from point to point over the surface of the oxide coating and activates the coating, the value of the discharge current being controlled during the activation process so as to lie between limits at which the discharge is maintained in said highly mobile spark condition until the activation of the coating by said method has been completed.

2. The manufacture of a cold-cathode gas-filled electric discharge device of the type in which the cathode consists of a metal support carrying on at least one surface an electron emissive coating containing one or more metal oxides of lower work function than the metal of the support, wherein the oxide coating of the cathode is activated by a method which comprises connecting the oxide-coated cathode to the negative terminal of a direct current supply, connecting another electrode of the device to the positive terminal of the supply, and passing an electric current between the cathode and said other electrode whilst the envelope of the device is filled with an ionisable gas filling at a pressure of between 5 and 15 millimetres of mercury, said current being such that there is obtained a highly mobile spark discharge which moves rapidly from point to point over the surface of the oxide coating and activates the coating, the value of the discharge current being controlled during the activation process so as to lie between limits at which the discharge is maintained in said highly mobile spark condition until the activation of the coating by said method has been completed.

3. The manufacture of a cold-cathode gas-filled electric discharge device of the type in which the cathode consists of a metal support carrying on at least one surface an electron emissive coating containing one or more alkaline earth metal oxides of lower work function than the metal of the support, wherein the oxide coating of the cathode is activated by a method which comprises connecting the oxide-coated cathode to the negative terminal of a direct current supply, connecting another

electrode of the device to the positive terminal of the supply, and passing an electric current between the cathode and said other electrode whilst the envelope of the device is filled with an ionisable gas filling at a pressure below the final gas filling pressure of the device, said current and pressure being such that there is obtained a highly mobile spark discharge which moves rapidly from point to point over the surface of the oxide coating and activates the coating, the value of the discharge current being controlled during the activation process so as to lie between limits at which the discharge is maintained in said highly mobile spark condition until the activation of the coating by said method has been completed.

4. The manufacture of a cold-cathode gas-filled electric discharge device of the type in which the cathode consists of a metal support carrying on at least one surface an electron emissive coating containing one or more metal oxides of lower function than the metal of the support, wherein the oxide coating of the cathode is activated by a method which comprises connecting the oxide-coated cathode to the negative terminal of a direct current supply, connecting another electrode of the device to the positive terminal of the supply, and passing an electric current between the cathode and said other electrode whilst the envelope of the device is filled with an ionisable gas filling at a pressure below the final gas filling pressure of the device, said current and pressure being such that there is obtained a highly mobile spark discharge which moves rapidly from point to point over the surface of the oxide coating and activates the coating, the value of the discharge current being controlled during the activation process so as to lie between limits at which the discharge is maintained in said highly mobile spark condition until the activation of the coating by said method has been completed and wherein this primary activation process is followed by a secondary activation process in which a series of short duration spark discharges, having peak currents of several amperes, are passed between the cathode and at least one other electrode of the device, with the cathode acting as the negative

electrode, whilst the envelope of the device is filled with an ionisable gas filling at approximately the final gas filling pressure of the device.

5. The manufacture of a cold-cathode gas-filled electric discharge device of the type provided with an anode, a cathode and at least one other electrode located in line with and between the anode and cathode, and in which the cathode consists of a metal support carrying on at least one surface an electron emissive coating containing one or more metal oxides of lower work function than the metal of the support, wherein the oxide coating of the cathode is activated by a primary method which comprises connecting the cathode to the negative terminal of a direct current supply, connecting the anode to the positive terminal of the supply, and passing an electric current between the cathode and anode whilst the envelope of the device is filled with an ionisable gas filling at a pressure below the final gas filling pressure of the device, said current and pressure being such that there is obtained a highly mobile spark discharge which moves rapidly from point to point over the surface of the coating and activates the coating, the value of the discharge current being controlled during this activation process so as to lie between limits at which the discharge is maintained in said highly mobile spark condition until the activation of the coating by said primary method has been completed, and wherein the primary activation process is followed by a secondary activation process in which a series of short duration spark discharges, having peak currents of several amperes is passed between the cathode and said other electrode of the device, with the cathode acting as the negative electrode, whilst the envelope of the device is filled with an ionisable gas filling at approximately the final gas filling pressure of the device.

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