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SPARK GAP ELECTRICAL APPARATUS

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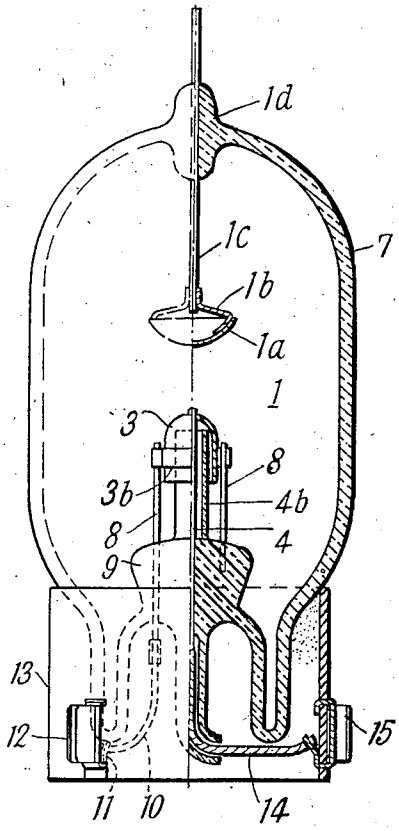

FIG. 2.

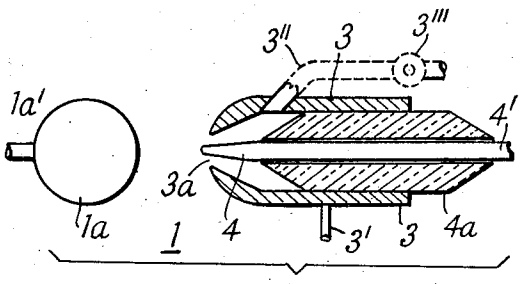

FIG. 1.

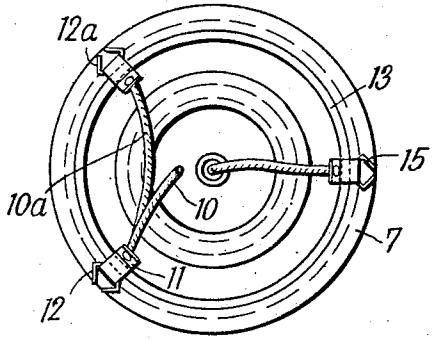

FIG. 3.

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2,433,755

SPARK GAP ELECTRICAL APPARATUS

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6 Claims. (Cl. 250—27.5)

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This invention relates to spark gap electrical apparatus adapted under predeterminable control to be tripped as nearly as possible at a predetermined instant, but more particularly at a plurality of accurately though not necessarily equally spaced time intervals at recurrence frequencies which may be of the order of several thousands per second.

The present application is closely related to the copending United States application Serial No. 514,863, which issued on May 14, 1946, as United States Patent No. 2,400,456, invented by Michael Edward Haine and John Millar Meek and copending United States application Serial No. 514,864 which issued on May 14, 1946, as United States Patent No. 2,400,457, invented by Michael Edward Haine, both applications filed December 18, 1943.

The primary object of the invention is to provide a novel trippable spark gap device which shall be reliable in operation as stated hereinafter, and the achievement of this presented a considerable problem which the features of the present invention, as hereinafter pointed out in the appended claims, have solved to an important extent as has been proved in practice.

Part of the original secret problem was to employ a trippable spark gap to provide heavy current substantially square-wave form or very steep-fronted impulses of substantially constant amplitude of the order of several hundred amperes each at recurrence frequencies of from one hundred to several thousand per second, the impulses being sharply defined so as not to overlap one another and being in some cases of the order of one or a few microseconds duration each.

In the accompanying drawings:

Fig. 1 is a purely diagrammatic view of a spark gap per se in accordance with the invention.

Fig. 2 is an elevation, half in section, of an enclosed and preferred form of the spark gap according to the invention, and

Fig. 3 is an underneath plan view of the device shown in Fig. 2.

Referring to Fig. 1, the spark gap device according to the invention comprises a cathode *1a* which is conveniently a sphere at least on that part thereof which faces the anode **3** which as shown comprises a tubular member but having a substantially spherical left-hand end wherein there is an aperture *3a* through which extends the rounded end of the slim trigger electrode **4** which in the arrangement diagrammatically shown in Fig. 1 is held within and spaced from the tubular anode **3** by the insulating sleeve *4a*

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which serves the further purpose hereinbefore stated. The cathode *1a* has a terminal or connector *1a'*, the anode **3** has a terminal or connector **3'** and the trigger **4** has its terminal or connector **4'**. The insulator *4a* may assume various other forms, conveniently that shown at *4b* in Fig. 2 to be hereinafter described. As hereinbefore indicated the presence of the insulator *4a* causes the potential gradient to be augmented at the surface of the trigger electrode **4** for a given trigger voltage pulse so that the corona is suddenly produced along with the arrival of the trigger voltage pulse. The radial width or the surface spark-over distance of the insulator *4a* must be large enough to obviate surface spark-over on the application of the trigger pulse. At **3''** is shown a pipe going to the interior of the electrode **3**, and at **3'''** is a pump for causing gas to flow through the aperture *3a*.

Concerning spark gaps enclosed in sealed chambers, we have made further extensive research, using glass bulbs. With a filling of air it was found that nitrogen-peroxide was rapidly formed, causing the gap to arc. We tried various gases of good chemical stability, particularly nitrogen and inert gas, especially argon, at various pressures and with varying results. It was found that in general argon individually was not very satisfactory at high triggering pulse frequencies, due to the fact that the gas atoms attain a metastable state and recover therefrom slowly, that is to say the atoms recover in a time which may be as long as 0.001 or even 0.1 second. A filling of nitrogen gave poor results, probably due to the formation of metastable atoms also. Whilst a filling of hydrogen gave good operating results the life of the device was shortened by reason of too rapid wear of the electrodes, particularly the trigger electrode, possibly due to the formation in the discharge of unstable hydrides of the electrode materials, which subsequently split up, depositing the metal on the tube walls and on the electrodes in powder form.

We are aware that in Geiger counters the presence of a quantity of oxygen with the argon filling causes a rapid "quenching," that is, recovery from the metastable state: see Journal of The Franklin Institute, May and June 1941.

We have found by research that very good operational results are obtained when the gas filling comprises argon with from about one to five per cent oxygen content at pressures from 15 to 60 pounds per square inch. Even better results may be expected with such a mixture at greater pressures when it may be preferable to use metal con-

tainers instead of glass ones. This subject matter forms a feature of the present invention.

It will be appreciated that when our spark gap device is enclosed in a sealed chamber its operation is unaffected by changes in altitude. We have found with glass containers that the noise of the sparking is very materially reduced.

According to the at present preferred constructional form of the invention shown in Figs. 2 and 3, the spark gap 1 is enclosed within the relatively thick walled glass bulb 7, the cathode 1*a* comprising per se a pressed molybdenum spherical portion fixed by the portion 1*b* to the stem 1*c* which passes through the seal 1*d* at the top of the bulb.

The molybdenum anode 3 is spot welded to metal straps 3*b* which are spot-welded to metal posts 8 one of which as shown passes through the seal 9 and is exteriorly connected to an insulated stranded conductor 10 which is soldered to a tab 11 of an external contact member 12 fixed to the tubular insulating cap 13. The conductor 10 is continued from the tab 11, as shown at 10*a*, to another contact member 12*a* spaced 90° from the contact member 12.

The trigger electrode is in the form of a rod 4 which passes through the seal 9 and is connected exteriorly to the insulated stranded conductor 14 connected to the external contact member 15 which is symmetrically spaced from each of the contact members 12 and 12*a*. The insulation 4*b* between the trigger electrode 4 and the anode 3 is in the form of a glass tube fused to the top of the seal 9.

With further reference to the theory of operation of spark gap devices in accordance with the present invention, it may be explained that, as is per se known, the voltage gradient required to cause breakdown of the gap with uniform field is that which causes an electron "avalanche," which crosses the gap to the anode and is of such intensity that the radial field produced by the positive-ion space-charge in the avalanche system is of the order of the interelectrode field since the space-charge forms an effective point on the anode surface. A positive streamer then develops from anode to cathode to form a conducting "filament" bridging the gap.

The voltage required to cause the propagation of the positive streamer across the gap is much lower than that required to cause the electron avalanche which leads to the initiation of the streamer, and corresponds roughly to that for breakdown between a positive point and an earthed plane. The field distortion produced by the positive space-charge in the avalanche is simulated in the spark gap device of the invention by the field distortion produced by the trip pulse on the trigger electrode, and the breakdown voltage of the gap is thereby reduced by an amount approximately given by the difference in breakdown voltage for a sphere-to-sphere gap and a gap of the same length between a positive point and an earthed sphere. Thus for a gap of 1 cm. between spheres each of 1.3 cm. diameter, the breakdown voltage in air at normal atmospheric pressure is 29 kv., whereas for the positive point-to-sphere gap of the same length the breakdown voltage is 12 kv. approximately, which is a depression of sixty per cent.

We have found that the magnitude of the potential pulse applied to the "point" electrode also affects the depression of the breakdown voltage of the main gap. It not only creates a radial field at the point and initiates a positive streamer, but it also augments the main field across the gap. Thus the higher the applied pulse voltage the greater is the depression, other conditions being unchanged.

It will be understood by those skilled in the art that by a "point" electrode there is not necessarily herein involved one having a very sharp point, the requirement being a slim trigger electrode of such shape in relation to the relatively large spherical or like shape of the main electrode for giving the main field, as to cause a sufficient distortion and concentration of this field whereby the depression of the spark-over voltage is of the order of thirty per cent and upwards, according to varying conditions of use. With regard to the life and stability of the device as determined by electrode wear, we have found that superior results are obtained when the electrodes or parts thereof are formed of molybdenum or tungsten.

In general for any given electrode spacing it is, of course, the uniform field gap which requires the highest voltage for breakdown. The spark gap arrangement according to the invention will operate with voltage pulses of either polarity in conjunction with either polarity of the high voltage electrode of the main gap. However, the best operation for any given polarity of high voltage electrode is obtained when a pulse of opposite polarity is applied to the "point" electrode, and the greatest depression of breakdown voltage occurs for a positive voltage pulse when the high voltage electrode is of negative polarity. The fact that the depression is not so great for a negative pulse as for a positive pulse may be explained, since the negative streamer does not propagate as readily as a positive streamer, and the voltage required to cause breakdown between a negative point and an earthed plane is about twice that for a positive point, although it is still considerably below that for the uniform field.

It will be appreciated that in the arrangement of spark gap illustrated in the drawing with the active end of the trigger electrode 4 approximately coincident with the active surface of the main electrode 3, the potential at which the electrode 4 is normally biased is the same, or nearly the same, as the normal potential of the electrode 3.

The present invention provides a small unitary structure embodying two main electrodes of such shape or form as to give maximum breakdown voltage for a given spacing by reason of there normally being between these main electrodes a substantially uniform field, while a trigger electrode is provided which is essentially a slim member arranged and provided in relation to the main electrodes in such manner as not normally to cause a field which will appreciably interfere with the normal field between the main electrodes. Preferably, the main electrodes have substantially spherical ends facing each other, while one of them is formed with an axial perforation through which the slim trigger electrode extends. This slim trigger electrode, while being by reason of the external circuits, such as disclosed in the aforesaid application Serial No. 514,863, "biased" to a potential not incompatible with the space potential between the main electrodes, is such that when the steep-fronted triggering pulse potential is applied to the slim trigger electrode, considerable field distortion is set up tending to cause the gap to break down, namely between the main electrode which is opposite the electrode which is associated with the trigger electrode, and the latter, and then immediately afterwards in

the shorter gap between the trigger electrode and the main electrode with which it is associated.

Some of the uses to which the invention may be applied are set forth in the aforesaid application Serial No. 514,863.

We claim:

1. A trippable spark gap device comprising input and output main electrodes fixed apart appreciably beyond their normal spark over spacing in relation to a predetermined voltage to be normally applied across the gap, a fixed trigger electrode associated with one of said main electrodes, an envelope enclosing said electrodes, and at least one inert gas mixed with a small proportion of a quenching gas filling said envelope at a pressure above atmospheric pressure, said trigger electrode having a tip of small radius of curvature and being located sufficiently near to the main electrode with which it is associated that when normally appropriately biased there is so little disturbance of the substantially uniform field between said main electrodes that when the normal voltage is applied breakdown is avoided with appreciable tolerance, and when a triggering voltage pulse is applied to said trigger electrode breakdown is caused due to appreciable distortion of said field.

2. A spark gap device as defined in claim 1, wherein said inert gas is argon and said quenching gas is oxygen in the range of proportions substantially of from one to five per cent of oxygen, and wherein at least the active surfaces of said electrodes are of a refractory metal.

3. A trippable spark gap according to claim 1, wherein said inert gas is argon and said quenching gas is oxygen.

4. A trippable spark gap according to claim 1, wherein at least the active surfaces of said electrodes are of refractory metal.

5. A spark gap device comprising relatively spaced apart anode and cathode, the anode having an aperture therein, a slim bluntly pointed auxiliary trigger electrode mounted in fixed position and spaced from the edges of the aperture in the anode, a sealed envelope enclosing the electrodes, and a mixture of an inert gas and a small proportion of a spark quenching gas filling the envelope at a pressure above atmospheric pressure.

6. A spark gap device comprising input and output main electrodes having substantially spherical surfaces which are spaced apart and face one another and provide a main discharge gap, one of said electrodes having an axial aperture therein, a slim bluntly pointed auxiliary trigger electrode mounted in fixed relation with the main electrodes and extending through said aperture beyond the respective main electrode and toward the other main electrode and spaced radially from the surrounding edge of the aperture to provide a gap shorter than the main discharge gap, a sealed envelope enclosing the electrodes, and a gaseous medium comprising a mixture of an inert gas and a small proportion of a spark quenching gas filling the envelope at a pressure above atmospheric pressure.

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