

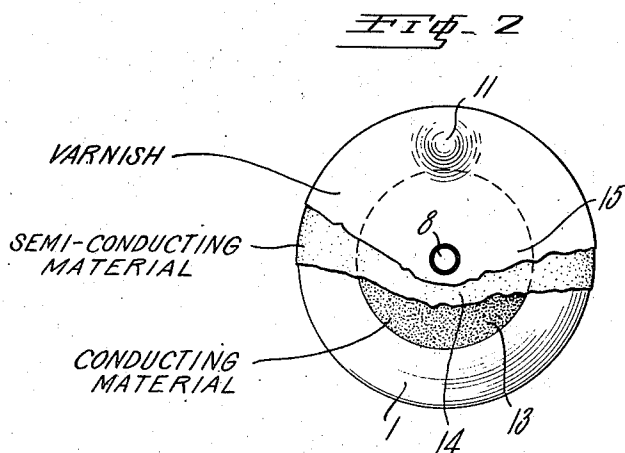
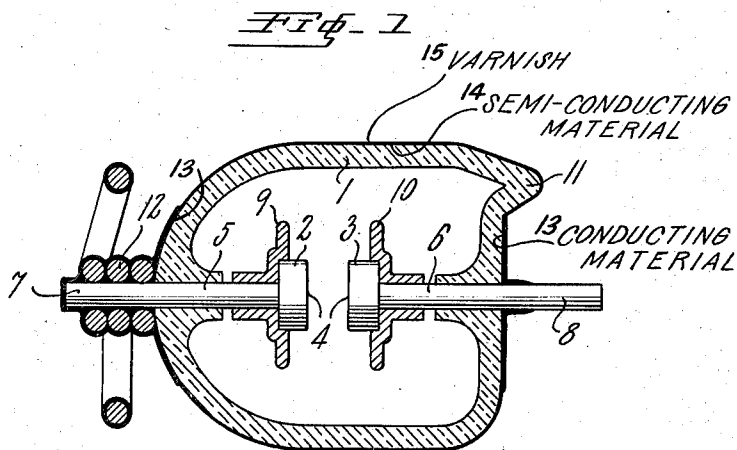
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ELECTRIC SPARK GAP

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ELECTRIC SPARK GAP

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The present invention relates to electric spark gaps, and particularly to those for oscillatory electric circuits, such as have been used in electric ignition systems of the capacity discharge type for internal combustion engines, for example, as shown in Fig. 1 of Patent 2,030,228 and also in lightning arresters, and in electronic and other electrical devices.

Under the condition that the applied voltage across the gap is increased from its initial value to the breakdown value at an infinitely slow rate of about 10 volts per second or less, the breakdown voltage between two separated electrodes forming a spark gap in space, herein termed a "steady state" breakdown voltage, depends on the gap distance between the electrodes, the composition and density of the atmosphere in the gap, the size and shape of the electrodes at the two points between which the spark occurs, and the distribution of the bound electrical charges in the space surrounding the gap. However, the value of the breakdown voltage is materially affected by the steepness or slope of the wave front and by the shape of the wave front of the applied voltage when it is increased in value at a much higher rate measured in kilovolts per micro-second and herein termed the "transient" breakdown voltage. The charge, mass, cross sectional area, and geometrical position of all free charged particles within the gas in a sphere of diameter having the two electrodes as poles, in addition to the foregoing factors affecting the steady state breakdown voltage, affect the transient breakdown voltage, and likewise the work function of the electrode material expressed in electron volts as represented by the kinetic energy which an electron within the material must have, in a direction normal to the surface of the electrode, in order to escape into free space. Furthermore, the ratio of the steady state breakdown voltage is affected, but to a comparatively slight degree, by the preceding breakdown discharge. In a spark gap of the kind herein disclosed, it is desirable to maintain the transient breakdown voltage as nearly constant as possible to thereby stabilize or render more uniform throughout its operative life, the action of the spark discharge in the circuit or devices with which it is associated. Such stabilization not only reduces the value of the maximum voltage required in the system to provide reliable ignition, but, as a result thereof, increases the altitude at which the system will operate on aircraft without electrical flash over.

In such spark gaps in general, it has been cus-

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tomary to assist in stabilizing or rendering uniform the transient breakdown voltage of the gap by sealing the spaced electrodes thereof in an envelope, usually of glass for insulating purposes, to thereby reduce variations in performance due to surrounding atmospheric conditions resulting from such variables as altitude, temperature and humidity, and also by using certain metals and alloys for the electrodes with different gap separation and with different gases and admixtures thereof at different pressures in the envelope. In certain cases also, certain activating agents, and certain shapes of electrodes, with different shape and size of electrode shields and envelopes thereof have been used. Certain of such features are shown in Patent 2,122,932. Notwithstanding such features, these spark gaps deteriorate and change in performance in the operative period between overhauls of the devices or apparatus with which such spark gaps are associated, particularly in the case of spark gaps installed in proximity to grounded devices. The grounded device causes distortion of the electric field between the electrodes forming the gap, and deflect the sparks in the gap to the inside wall of the envelope. This lowers the breakdown voltage across the gap and renders it unstable or erratic in performance. Furthermore, the sparks so deflected quickly cause a metallic deposit on the inside of the envelope, lowering the breakdown voltage still more with still further instability and erratic performance of the spark gap.

In accordance with my invention, the operation of spark gaps in general in various kinds of oscillatory circuits or electrical devices is more or less stabilized throughout the operative period thereof whether or not some or all of the aforementioned features of prior spark gaps are used. I accomplish this by providing means for maintaining a substantially uniform voltage gradient between the two electrodes of the gap, irrespective of the proximity of outside grounded devices. The deflection of the spark discharges is thereby reduced or eliminated, and the distribution of point electrical charges in the space outside the envelope is stabilized or the variation of their effect is rendered negligible. Such means within my invention may comprise a conducting or semi-conducting coating, or a high resistance such as a winding or otherwise electrically shunted across the electrodes of the gap. Preferably this coating or other resistance is arranged outside the envelope of the spark gap, whether along the outside surface thereof or on a suitable support spaced therefrom, so as to be un-

affected by the heat or the chemical action from the spark discharges. Still more preferably the outside of the envelope is completely covered with a suitable semi-conducting coating extending to the outwardly projecting terminals of the electrodes forming the gap, and the envelope is symmetrical and coaxial with respect to the gap so that the electric field is uniform and the voltage gradient between the electrodes is substantially constant throughout. This condition is then maintained even though the potential of points outside of the envelope, and near thereto, are caused to assume values which otherwise would distort or deflect the field between the electrodes and thereby render the gradient no longer constant. Also, preferably, good electrical contact between this semi-conducting coating and the electrodes forming the gap is made by a relatively high conducting coating which is arranged on the outside surface of the envelope around the terminals projecting therefrom, and which extends from both terminals to a place overlapping the semi-conducting coating to reliably connect the latter to both electrodes. Furthermore, these coatings are mechanically protected by an outside layer of varnish, shellac, or the like, or by an admixture of the semi-conducting material therein.

During the period of time that the voltage applied to the gap is increasing, a displacement current flows between one electrode and the grounded device, the other electrode of the spark gap being at ground potential prior to the breakdown of the gap. The magnitude of this displacement current is preferably made negligibly small, say 5% or less as compared to the conduction current through the coating, so that the potential at all points on the surface to which the coating is applied will be determined almost entirely by the conducting coating rather than by the grounded device in proximity to the gap.

These and other objects and advantages of my invention will appear from the following description of its preferred form in application, as an example, to a spark gap for a capacity discharge type of ignition system for an internal combustion engine for aircraft. In the drawings,

Fig. 1 is a central section, partly in elevation, of this preferred form of spark gap; and Fig. 2 is an end elevation of the spark gap with portions of the superposed coatings removed.

Referring to the drawings, the reference numeral 1 designates an envelope or container of uranium glass. Its tungsten electrodes 2 and 3 have their proximate faces spaced about 3 mm. apart to form a gap 4 therebetween, and the tungsten rods of stems 5 and 6 project in a sealed manner through the envelope to form the outside terminals 7 and 8 of the spark gap. The shields 9 and 10 are of thin metal to assist in preventing eroded electrode material from depositing on the envelope in such manner as to form a leakage path in a shunt with the gap, the walls of which are arranged symmetrically and coaxially with respect to the gap 4 and with the uppermost and lowermost parts of the shields 9 and 10 at least as distant as the axial length of the gap 4. Before the sealing tubulation at 11 is fused off to seal the envelope, and before the envelope is evacuated and then filled with argon, at least 98% pure, to an absolute pressure of 30 to 75 cms. of mercury, a few drops of radio-active solution, as a very dilute solution of radium bromide in water, is introduced within the envelope. The order of magnitude of the transient break-

down voltage of such a gap when new as used with an aircraft type of capacity discharge ignition systems is around 2000 crest volts. However, gaps of this general kind may be designed for a transient breakdown voltage of from 500 to 5000 crest volts depending upon the size and type of the transformer used in the circuit of the spark gap.

A spring connector 12 tightly gripping the rod 7 of the spark gap furnishes electrical connection to the electrode 2, and a suitable terminal (not shown) generally of a disconnectible type furnishes connection to the rod 8 and therethrough to the electrode 3.

Both ends of the spark gap, with the connector 12 installed as shown in the drawings, are separately dipped into a highly conducting solution such as a colloidal suspension of graphite in water. Thus the outside of envelope 1 around the end thereof and over terminal 8 is coated in a circular area, as shown at 13, with the Aquadag, and likewise the other end including the connector 12. This provides a good electrical connection between the respective rods 7, 8 and the surrounding end portions of the envelope. After the Aquadag has dried, the entire spark gap with connector 12 is then immersed in a solution of semi-conducting material 14, of a high resistance conductive coating material, over which is placed a coating of shellac. The highly conductive coating reliably connects the semi-conducting coating to both terminals 7 and 8 to form therewith a high resistance shunt electrically connected across the electrodes 2, 3. After that semi-conducting coating has dried, the spark gap and connector 12 are given a coating of insulating varnish 15 of heat- or air-drying type to protect the coatings underneath from rubbing off or from so readily being damaged. The terminal area of rod 8 is scraped or otherwise cleaned off, as indicated in Fig. 1, to provide good electrical connection with the connector that may be installed at that end of the spark gap.

It will be understood that many metal-oxide glazes adherent to glass, and suspensions of charcoal in varnish, may be used for the semi-conducting coating with good results. So also sprayed metal or reduced platinum oxide of suitable kind may be used for the highly conducting coating around the terminals 7 and 8, and shellac of suitable kind may be used instead of the varnish. Furthermore, the high resistance coating may be directly admixed with the outside protective coating so that the two coatings are thus combined into one. However, the coatings as above specified are preferred at this time. Furthermore, it will be understood that other suitable materials and dimensions of the envelopes, gaps, electrodes, stems and shields may be used, and likewise other mixtures and pressures of gas within the envelope.

The resistance of the completed coating between the terminals 7, 8 can be very high, of the order of 10 megohms or more, and still be adequately conducting to maintain a reasonably uniform electric field across the gap 4. The exact value of the maximum permissible resistance for satisfactory operation depends in each case upon the geometry of the spark gap, the location of the nearby grounded bodies and the rate of use of voltage applied to the gap, and can be predetermined in well known manner. With such uniform field, or substantially so, the voltage gradient is substantially uniform between the electrodes 2, 3, irrespective of the location with

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respect to the spark gap of outside grounded devices, as for instance the grounded metallic radio-shielding harness in which the spark gap and other devices are contained. The deflection of the rapidly-recurring spark discharges across the gap 4 is thereby reduced or eliminated, and the distribution of point electrical charges in the space outside the envelope 1 is stabilized or their effect on the spark discharges is rendered negligible. In this way little or no metallic deposit forms on the inside surface of the envelope resulting from erosion of the electrode or electrodes, and therefore there occurs no substantial decrease in the electrical resistance of the gap throughout its useful life such as would render the gap erratic or unstable. Accordingly, the transient breakdown voltage of the gap is maintained substantially constant, thereby stabilizing or rendering more uniform the action of the electric discharge in the circuit or devices with which the spark gap is associated, and also reducing the voltage required in the system to provide reliable ignition for aircraft engines while even operating at high boost or lean mixture and at high temperatures of operation, and also increasing the altitudes at which the system will operate without electrical flashover. Such conditions obtain throughout the entire operating period between overhauls of 450 hours or more.

A 500 hour test on a large number of externally coated spark gaps as specifically described herein, and a substantially similar number of uncoated but otherwise identical spark gaps, using about 2000 crest volts at a thousand sparks per minute, showed for the coated spark gaps about 10% deviation in breakdown voltage against an average maximum deviation of about 15% for the uncoated spark gaps, and a reduction in conductivity from about one megohm resistance to a practically infinite value of resistance for the coated gaps. Such deviation as occurred with the uncoated gaps may result in the absence of firing at some spark plugs of aircraft engines.

It will be understood that many modifications and changes may be made in the structures and use of the spark gaps herein disclosed without departing from the spirit of the invention as covered by the broad terms of the appended claims.

Having thus described the invention, what I claim is:

1. An electric spark gap comprising an envelope, electrodes mounted within the envelope, said electrodes being sufficiently closely spaced to each other to provide a spark gap, and a semi-conducting coating externally of and entirely enclosing said envelope, said coating being sufficiently conductive to conduct bound charges, but not sufficiently conductive to short circuit the gap, said semi-conducting coating being electrically connected with at least one of said electrodes.

2. An electric spark gap comprising an envelope, electrodes mounted within the envelope, said electrodes being sufficiently closely spaced to each other to provide a spark gap, and a semi-conducting coating externally of and entirely enclosing said envelope, said coating being suffi-

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ciently conductive to conduct bound charges, but not sufficiently conductive to short circuit the gap, and relatively higher conducting means connecting said semi-conducting coating with at least one of said electrodes.

3. An electric spark gap comprising an envelope, electrodes mounted within the envelope, said electrodes being sufficiently closely spaced to each other to provide a spark gap, and a semi-conducting shunt externally of and entirely enclosing said envelope, said shunt being sufficiently conductive to conduct bound charges but not sufficiently conductive to short circuit the gap and relatively higher conducting means connecting said semi-conducting shunt with at least one of said electrodes.

4. An electric spark gap comprising an envelope, electrodes mounted within the envelope, said electrodes being sufficiently closely spaced to each other to provide a spark gap, and a resistor externally of and entirely enclosing said envelope, said resistor being sufficiently conductive to conduct bound charges, but not sufficiently conductive to short circuit the gap and relatively higher conducting means connecting said resistor with at least one of said electrodes.

5. An electric spark gap comprising an envelope of insulating material, electrodes mounted within the envelope, said electrodes being sufficiently closely spaced to each other to provide a spark gap, and a semi-conducting coating externally of and covering the entire surface of said insulating material, said coating being sufficiently conductive to conduct bound charges, but not sufficiently conductive to short circuit the gap, said semi-conducting coating being electrically connected with at least one of said electrodes.

6. An electric spark gap comprising an envelope of insulating material, electrodes mounted within said envelope, said electrodes being sufficiently closely spaced to each other to provide a spark gap, and a semi-conducting coating externally of and extending over the entire surface of said insulating material, said coating being sufficiently conductive to conduct bound charges, but not sufficiently conductive to short circuit the gap, and relatively higher conducting means electrically connecting said semi-conducting coating with at least one of said electrodes.

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