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R. B. EDMONSON

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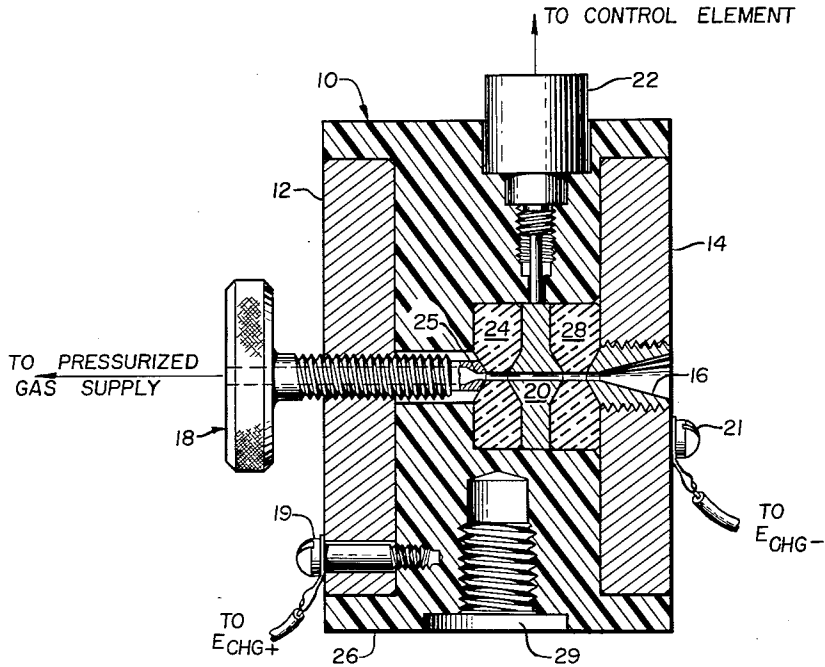


Fig. -1

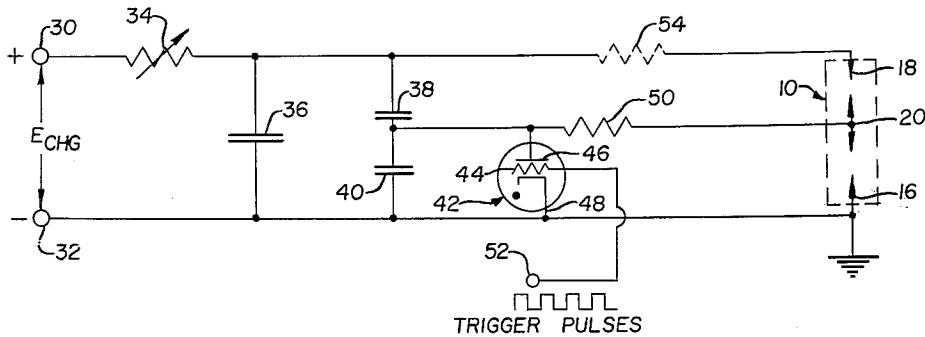


Fig. -2

INVENTOR.
ROBERT B. EDMONSON

BY *D. Gordon Angus*
ATTORNEY

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SPARK GAP

Robert B. Edmonson, Upland, Calif., assignor to Aerojet-General Corporation, Azusa, Calif., a corporation of Ohio

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This invention relates to an improved spark gap and a control circuit therefor.

Both photomicrography of living specimens and shadowgraph photography of high speed phenomena, such as compressible flow in wind tunnels and in high speed projectile flight, require as an indispensable element a high intensity light source of extremely short duration and small effective area. The spark gap light source has come to be favored over alternative means as possessing a number of distinct advantages, among them being the extremely short duration and high intensity of the light flash. The spark gap has also come to be the favored ignition means in power plants such as the internal combustion engine of the automobile and airplane, and the rocket engine. But reliable spark gap ignition is difficult to obtain at high altitudes.

Spark gaps employed have been primarily of the two electrode type where an electric discharge is initiated and maintained between two electrodes by application of a voltage thereto, the value of voltage required being dependent upon the distance between the electrodes, their geometry, and the pressure and nature of the gas between them. This configuration, however, is not entirely satisfactory as the gap breakdown, hence the ignition of the fuel or light flash, will not occur with the same applied voltage upon each occasion nor the same time interval after application of the voltage to the electrodes.

To overcome these disadvantages, various types of control means have been employed in conjunction with the spark gap. Among these are thyatron circuits and auxiliary gaps. Both, however, are usually connected in series with the controlled gap and, in addition to other resultant disadvantages, thereby provide positive control of breakdown time and voltage at the expense of circuit energy dissipation in other than the discharge.

It is, therefore, the principal object of the present invention to provide a high efficiency controllable spark discharge system wherein practically all of the circuit energy is impressed across the spark gap.

Another object of this invention is to provide a multi-electrode spark gap assembly that will reliably discharge at the same time interval after application of each identical triggering voltage.

A further object of the present invention is to provide an improved spark gap light source of high intensity and short duration.

Still another object of this invention is to provide a novel means for and an improved method of starting a rocket engine without altitude limitations.

In its principal aspect, the present invention comprises a novel multi-electrode spark gap assembly and an improved control circuit for use in conjunction therewith. By spark is meant that electric discharge which takes place between electrodes in response to a high voltage applied thereon. Essentially, the gap assembly includes three electrodes situated within a common housing which, together with non-current conducting spacer members, form a confined channel for the spark dis-

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charge. A feature of the invention is provision of a hole through the second or trigger electrode to allow propagation of the spark to the third or cathode electrode which also has an opening therethrough to allow exit of spark light and/or spark gas from the assembly. Another feature of the invention is provision of means for maintaining pressure within the confined spark channel irrespective of the pressure environmental to the housing, affording use of the gap for rocket engine ignition irrespective of altitude.

The control circuit includes an energy storage capacitor shunted across the gap cathode electrode and anode electrode. A voltage division network, such as a pair of small serially connected capacitors are also connected across the storage capacitor. The trigger electrode of the gap is connected to a common point of connection between the two capacitors, thereby placing the trigger electrode at a potential intermediate that of the gap cathode and anode. A thyatron or other control element is placed across the gap trigger and cathode electrodes. When an actuating pulse is fed its control electrode, the thyatron begins to conduct, thereby placing the gap trigger electrode at the same potential as the gap cathode. Although the potential across the entire gap assembly remains unchanged, the potential gradient between the gap anode and trigger electrodes sharply increases, resulting in a voltage breakdown. Because of the hole through the trigger gap, the breakdown propagates throughout the entire channel, completing the discharge to the cathode electrode. As the cathode electrode also has an opening therethrough, the resulting high pressure gas exits to provide a high intensity, high temperature light and ignition source.

These and other objects, aspects, features and advantages of the invention will be apparent to those skilled in the art from the following more detailed description taken in conjunction with the appended drawings, wherein:

Figure 1 is a central longitudinal vertical section of the triple electrode gap assembly of the present invention; and,

Figure 2 is a schematic circuit diagram of the entire multi-electrode gap assembly and the control circuit therefor.

Figure 1 shows in detail the construction of a preferred embodiment of the triple electrode spark gap assembly 10, the principal components of which are mounted within an electrically non-conducting housing 26. The anode electrode 18 threads within a metallic mounting disc 12 which is recessed within the housing 26. Electrical connection from the anode electrode 18 to associated circuitry is made by contact with a screw 19 placed through the mounting disc 12 into the housing 26. A first cylindrical ceramic spacer 24 having a central coaxial cavity separates the anode 18 from the trigger electrode 20, itself a cylindrical disc of a conducting material with a central cavity therethrough. A trigger electrode plug 22 is arranged in the housing 26 in direct physical and electrical contact with the trigger electrode 20 to provide easy access for electrical connection to associated circuitry from the trigger electrode 20 which is arranged with the first ceramic spacer 24 within a hollow excavation in said housing 26. A second cylindrical ceramic spacer 28, also having a coaxial central cavity separates the trigger electrode 20 from the cathode electrode 16 which is placed as an insert within a second metallic mounting disc 14 arranged within the electrode housing 26. Alternatively, the cathode electrode 16 could be fabricated as an integral part of the second disc 14. Electrical connection of the cathode electrode 16 with associated circuitry is effected by connection to a screw 21 inserted within the second metallic mount 14

and threaded into the housing 26, not shown. The cathode electrode 16 also has a central coaxial cavity which allows the expansion of the hot gas resulting from the spark discharge and permits escape of light to a suitable optical system or heat to a combustible mixture. The anode electrode 18, hollow first spacer 24, trigger electrode 20, hollow second spacer 28, and conically excavated cathode electrode 16 together form a confined channel in which a spark discharge is propagated, resulting in a high intensity light flash as viewed from the conically diverging exit of the cathode electrode 16. Provision of a hollow trigger electrode 20 will be seen to afford more positive control of the discharge, but additionally, such a configuration does not interfere with the optical efficiency of the system. Similarly, hollowing the cathode electrode 16 increases its life as such construction affords a maximum cathode area thereby minimizing the occurrence of cathode sputtering. Construction of the assembly 10 with the use of ceramic spacers 24, 28 provides a unit having high interelectrode capacities, which, in the instant application, is a factor that can be utilized to eliminate unnecessary and excess circuitry. The assembly 10 may be physically arranged as desired by placement on a support member 29, shown here as being threaded within the housing 26.

The spark gap assembly 10 of the present invention may easily be adapted for starting of rocket engines irrespective of altitude. Reliable, controllable spark discharge may be achieved with any confined channel gap, and particularly with the apparatus of the present invention, so long as the pressure within the channel is maintained preferably at atmospheric pressure, and in no event less than five (5) to six (6) pounds per square inch. Therefore, where the present gap assembly 10 is to be employed at high altitudes, a pressurized gas is introduced into the confined channel through a critical flow venturi nozzle 25 which, in the present embodiment, is machined within the anode electrode 18. A critical flow nozzle is one wherein the mass flow of the gas therethrough is primarily dependent upon the upstream pressure and is independent of the downstream or exhaust pressure. The mass rate of flow within the confined channel would, therefore, remain at a value dependent upon the previous adjustment of the gas supply, irrespective of the pressure of the rocket ignition chamber or the altitude of the rocket. The pressurized gas may be introduced to the channel through other electrodes or at other points of the assembly 10. Means of introducing a pressurized gas flow other than by a critical flow nozzle 25 may be used. By proper placement with relation to the propellant, the assembly 10 of the present invention may be employed to ignite liquid, solid or gaseous propellants.

Reference is made to Figure 2, a schematic diagram of circuitry providing positive control and high efficiency operation of the triple electrode assembly 10 of Figure 1. A storage capacitor 36 is connected between a charging voltage positive input terminal 30 and a charging voltage negative input terminal 32 connected to ground. A variable current limiting resistor 34 may be serially inserted between the capacitor 36 and one of the terminals 30 to provide control of the charging time constant of the capacitor 36. The gap anode 18 is connected to the positive terminal 30 through the limiting resistor 34 and the gap cathode 16 connects directly to ground. If desired, a small non-inductive resistance 54 of the order of ten ohms or less, may be inserted in series with the gap electrodes 16, 18, 20, to minimize the destructive phenomenon known as "sputtering," that is, the enforced migration of material from the cathode. Use of such a resistance will thereby increase the life of the cathode electrode 16 and also tend to limit "ringing" or oscillations within the gap 10. It is shown here connected between the anode electrode 18 and the limiting resistor 34. A pair of capacitors 38, 40, each of which is very much

less in value than the charging capacitor 36, are connected in series and together are arranged between the gap anode 18 and the gap cathode 16. The gap trigger electrode 20 is connected to the junction point between the capacitors 38, 40. Alternatively it is possible under idealized or specialized conditions, to dispense with these capacitors 38, 40 as the ceramic spacers 24, 28 holding the trigger electrode 20 contribute to the interelectrode capacitance among the several gap electrodes 16, 18, 20.

Additionally, the leakage resistance of the entire gap assembly will comprise a voltage division network of the resistance type, affording even more positive trigger control of the gap at the expense of very little circuit energy.

A unilateral current conducting device such as a thyatron 42 is employed as a gap control means, the thyatron anode 46 being connected to the gap trigger electrode 20 through an anode current limiting resistor 50 while the thyatron cathode 48 connects to the gap cathode electrode 16, and the control grid 44 is connected to a control grid input terminal 52. Other control means, such as an auxiliary gap, may be used.

In operation, a unidirectional potential is impressed across the storage capacitor 36 through the input terminals 30, 32 in the polarity shown. The voltage is of a value less than the breakdown potential of the gap 10 which is dependent upon the nature and pressure of the gas surrounding the electrodes, the distance between the electrodes, the configuration of the gap electrodes, and the nature of the gap cathode electrode 16. If, however, the trigger electrode 20 were to be brought to the same potential as cathode electrode 16, then the potential provides sufficient overvoltage for the gap 10 to provide an immediate discharge. A complete discussion of factors affecting breakdown potential in accordance with Paschens Law is found in Chapter VIII, "Electrical Conduction in Gases," pages 252-253, Principles of Electricity and Electromagnetism, by Gaylord P. Harnwell, McGraw-Hill Book Company, Inc., New York, New York, first edition, 1938.

The capacitor 36 charges from the unidirectional potential source. The small capacitors 38, 40 are also charged and at the same polarity as the storage capacitor 36. Thus, by virtue of common connection, the gap anode 18 is at a positive potential, the gap cathode 16 at ground potential and the gap trigger electrode 20 at a potential, depending upon the circuit voltage division, intermediate that of the gap anode 18 and gap cathode electrode 16. Similarly, the thyatron anode 46, connected to the gap trigger electrode 20, is at a positive potential with respect to that of the thyatron cathode 48, which is tied directly to the gap cathode electrode 16. At the time it is desired to create a spark discharge, a positive trigger pulse from an external source, not shown, is applied to the thyatron control grid input terminal 52 which causes the grid element 44 to assume a potential positive with respect to the cathode element 48, causing the thyatron 42 to "fire." In other words, the firing potential of the thyatron 42 has been exceeded, and the gas within is sufficiently ionized so that there is current flow from the anode 46 to the cathode 48. This current flow is simply the discharge of the divider capacitor 40 and any stray interelectrode capacity in parallel with it. Because of direct connection of the gap trigger electrode 20 to anode 46 through the limiting resistor 50, in the absence of any electric discharge between the gap anode 18 and the trigger electrode 20, the latter also assumes a potential substantially identical to that of the cathode electrode 16. The total circuit voltage is now impressed between the trigger electrode 20 and anode electrode 18 since the trigger electrode 20 is now nominally at cathode or ground potential. The abnormally steep voltage gradient created in the region between the gap anode electrode 18 and the trigger electrode 20 causes a spark discharge breakdown resulting in a small current flow

through the high value ohmic resistance 50. In the absence of a discharge between the trigger electrode 20 and the cathode 16, this current flow through the limiting resistor 50 provides sufficient potential drop such that electrode 20 is brought to the same nominal potential as the anode 18. This causes breakdown between the cathode 16 and trigger electrode 20, completing the spark discharge throughout the entire channel. Upon discharge of the capacitor 36, the cycle described begins again and the light source is ready for firing once the storage capacitor 36 is recharged. The repetition rate is determined by the charging rate and the thyatron trigger rate.

By way of example only, a system as shown in Figure 2 was constructed yielding excellent results. High intensity light flashes of a duration less than one microsecond were obtained. The circuit elements of the system were as follows:

Capacitor 36	-----microfarads--	0.1
Capacitor 38	-----micromicrofarads--	25
Capacitor 40	-----do-----	25
Thyatron tube 42	-----5C22 type	
Resistor 34	-----megohms--	1.5
Resistor 50	-----ohms--	100,000
Resistor 54	-----do-----	2.5
Triple electrode gap	-----As shown	
Charging voltage	-----volts--	8,000

These values are by way of example only and are not to be considered limiting as other values may be used. Where control elements other than the thyatron are employed, it may be possible to reverse the polarity of the charging voltage.

It is to be understood that the form of the invention herewith shown and described is to be taken as a preferred example of the same and that various changes in the shape, size and arrangement of the parts may be resorted to without departing from the spirit of the invention and of the scope of the appended claims.

What is claimed is:

1. A spark discharge system comprising, a storage capacitor connected to be charged from a high voltage current source, a spark gap having a first, second, and third electrode and having a confined spark channel, a unilateral current conducting device, said capacitor being also connected in parallel with the first and second gap electrodes, and said device being arranged in parallel with the second and third electrodes, whereby the third electrode assumes the electrical potential of the second electrode thereby inducing a voltage breakdown through the entire channel when said device is made conductive.

2. A system for the generation of high intensity, short duration spark discharges comprising, spark gap including in the order named, an anode, trigger and cathode electrodes arranged to form a confined spark channel, said trigger electrode having a passage therethrough, means for placing a difference of potential between said anode and cathode electrodes, and means for placing a potential on said trigger electrode which changes from a value intermediate said anode and cathode electrode potentials to the cathode potential, whereby the potential gradient between said anode and trigger electrodes is sharply increased to cause a spark discharge throughout the entire channel and means for introducing a gas into said confined channel at any desired pressure.

3. A system as described in claim 1, and in addition, a sonic flow venturi gas nozzle arranged to exhaust within said confined channel.

4. A system as described in claim 1, and in addition, means for maintaining the pressure within said confined channel above a predetermined value.

5. A system as described in claim 1, and in addition, means for maintaining the pressure within said confined channel above 5 to 6 pounds per square inch.

6. A system as described in claim 2 wherein said cathode electrode has a passageway therethrough.

7. A system for generation of a spark comprising, a gas discharge means having in the order named cathode, trigger and anode electrodes arranged to form a confined channel, an energy storage means connected to effect a difference in electrical potential between said cathode and anode electrodes, when said storage means is charged with energy a voltage division means in parallel connection with said storage means, an intermediate point of which is connected to place said trigger electrode at an electrical potential intermediate to that of said anode and cathode electrodes, when said storage means is charged with energy and a pulse actuated unilateral current conducting device arranged between said trigger and cathode electrodes to place said trigger electrode at the potential of said cathode electrode in response to a triggering pulse whereby the potential gradient between said anode and trigger electrodes is sharply increased to cause a gas discharge throughout the entire arc channel.

8. A system as in claim 7 and, in addition, a critical flow nozzle formed as an integral part of said anode electrode.

9. A high intensity, short duration spark light system comprising, a high potential current source, a voltage pulse source, a storage capacitor having two terminals, a first voltage dividing capacitor, a second voltage dividing capacitor, said first and second voltage dividing capacitors being joined in series, said storage capacitor being arranged in a parallel connection with said serially connected voltage dividing capacitors, said current source being connected to charge said storage capacitor, a spark gap having an anode, cathode and trigger electrode, an electron discharge device having an anode, cathode and control electrodes, a current limiting resistor, said gap trigger electrode being joined in electrical connection with the junction point between said first and second voltage dividing capacitors, said discharge device anode being connected to said gap trigger electrode through said current limiting resistor, said gap anode connecting to one terminal of said storage capacitor, said gap cathode connecting to the second terminal of said storage capacitor, said electron discharge device cathode electrode connecting to said gap cathode electrode, and said voltage pulse source connecting to said electron discharge device control electrode.

10. An assembly for the generation of a spark discharge within a confined channel, comprising, an anode electrode, a trigger electrode having an opening through the center thereof, a cathode electrode having an opening through the center thereof, a first non-conductive spacer element having a central cylindrical opening, said first spacer element being arranged to separate said anode and trigger electrodes, and a second non-conductive spacer element having a central cylindrical opening, said second spacer element being arranged to separate said trigger and cathode electrodes.

11. An assembly as described in claim 10 and, in addition, a nozzle through which gas is introduced and maintained at a desired pressure in contact with said electrodes.

12. A multi-electrode assembly for obtaining an electric discharge within a gas, comprising, in the order named, a first anode electrode of solid construction, a first non-conductive spacer element having a central cylindrical cavity therein, a second trigger electrode having a central cylindrical cavity therein, a second non-conductive spacer element having a central cylindrical cavity therein, a third cathode electrode having a central conical cavity therein diverging to the ambient, and a non-conductive housing within which all said spacer elements and electrodes are arranged to have a common longitudinal axis, the central cavities of said spacer elements and said cathode and trigger electrodes together with said anode electrode forming a confined channel for the electric discharge.

13. A method of generating a high intensity short duration spark comprising, charging an electrical energy storage device, applying the potential energy of said device to a multi-electrode gas discharge device resting in its non-conductive state, passing a continuous pressurized gas flow past the electrodes of said multi-electrode gas discharge device, placing a switching device having infinitesimal energy consumption in an electrically parallel arrangement with at least two of the electrodes of said gas

discharge device, and actuating said switching device to sharply increase the potential gradient within said gas discharge device whereby it changes to its conductive state.

References Cited in the file of this patent

UNITED STATES PATENTS

1,459,252	Plumm	June 19, 1923
2,509,005	Lord	May 23, 1950
2,592,520	Sackett	Apr. 8, 1952