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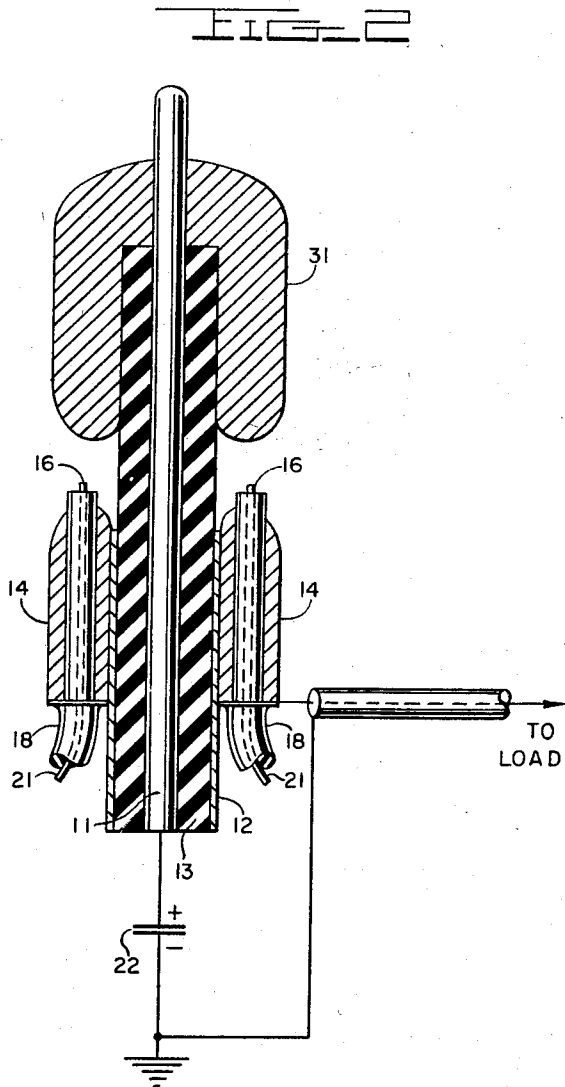
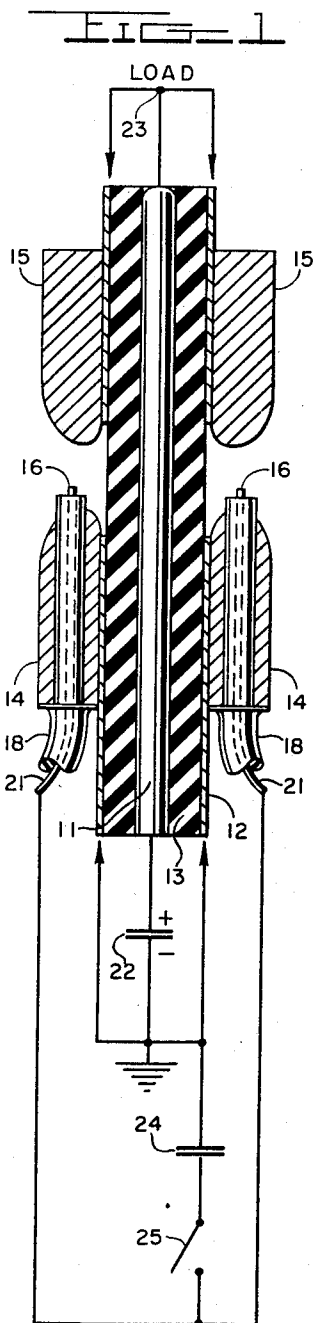
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COAXIAL MAGNETOHYDRODYNAMICS SWITCH DEVICE

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3 Sheets-Sheet 1



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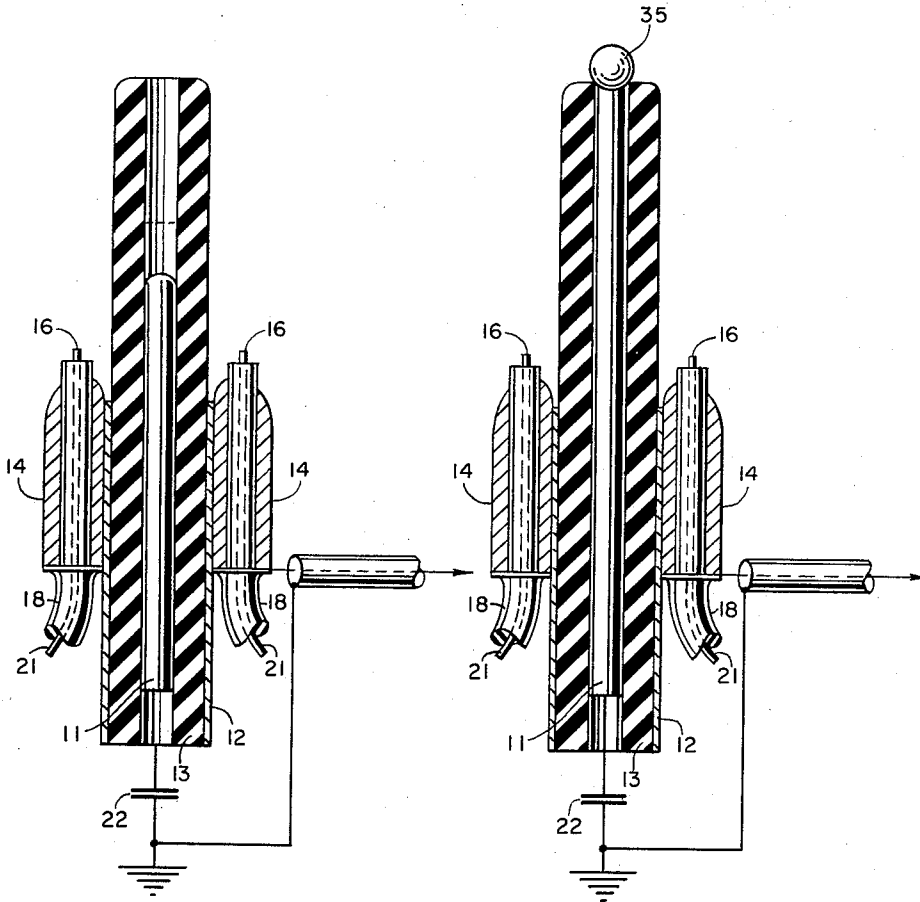
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FIG. 3

FIG. 4



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FIG-5

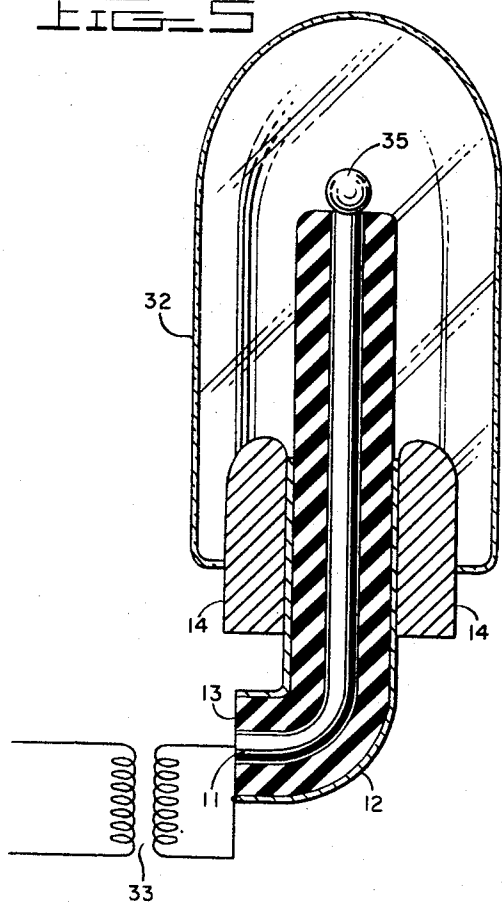


FIG-6

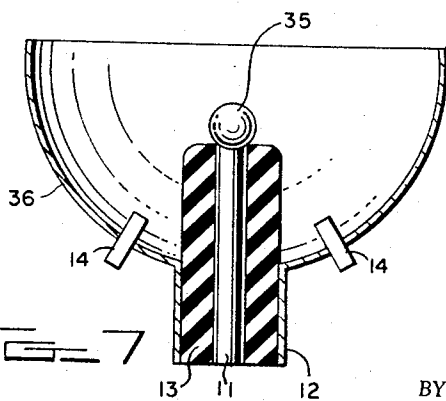
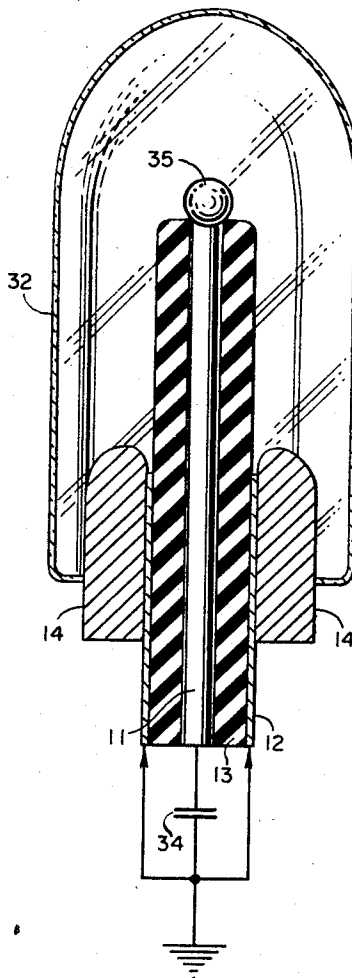


FIG-7

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COAXIAL MAGNETOHYDRODYNAMICS SWITCH DEVICE

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11 Claims. (Cl. 313—197)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to arc discharge switches and more particularly to high current, low inductance arc discharge switches of the coaxial magneto hydrodynamics type.

Heretofore arc discharges have been carried out between two electrodes to break down the medium between the electrodes. In the prior art devices, the arc between the electrodes "pinches down" toward the axis of the space between the electrodes. The localized arc produces heat which together with its inherent instability, affects the electrodes and insulation and thereby limits the number of times the switch can be used with high current discharges.

The present invention is directed to an arc gap switch of coaxial construction in which the arc is forced away from the gap area. Thus, the switch produces a high temperature, high velocity, inherently stable shock wave directed away from the switch to prevent damage to the insulation material and the electrodes. This is basically accomplished by opening the outer conductor of a coaxial transmission line to form a spark gap while leaving the inner conductor continuous. Such a switch can be fired many times which far exceed the number of firings with the prior art type of air gap switches of the high current type.

It is therefore an object of the present invention to provide a long lasting, simple and inexpensive arc gap switch adapted to coaxial geometry.

Another object is to provide an arc gap switch which is readily accessible for easy and quick adjustment of the electrode spacing or changing of the electrodes, if necessary.

Still another object is to provide an arc gap switch suitable for forcing the high temperature spark in the gap as well as metallic vapors from the electrodes formed during discharge, away from the electrodes, insulation and tickler protrusions.

A further object is to provide an arc gap switch that can be easily enclosed and used as a pressurized or vacuum type switch.

Yet another object is to provide a high current, low inductance switch suitable for many applications.

The exact nature of this invention as well as other objects and advantages thereof, will be readily apparent from considerations of the following specification relating to the annexed drawings, in which:

Fig. 1 is a cross sectional view of one embodiment of the invention which illustrates the relative parts of the switch connected in a workable circuit;

Figs. 2, 3, 4 and 7 are modifications of the switch shown by illustration in Fig. 1;

Fig. 5 illustrates a lamp made in accordance to the principle demonstrated by Fig. 4; and

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Fig. 6 illustrates a flashing lamp made in accordance to the principle demonstrated by the device of Fig. 4.

The device of the present invention is made in the form of coaxial conductors separated by an insulating material in which coaxial geometry is accomplished by passing a centrally located conductor together with its surrounding insulation, through the outer cylindrical conductor, which is opened to form two electrodes separated by an air gap. The magnetic field associated with the current through the inner conductor causes the arc discharge to be forced away from the ends of the electrodes and away from the insulation to prevent damage to the insulation or the electrodes. For the purpose of initiating breakdown of the air between the gap, tickler electrodes are provided to ionize the air in the air gap, causing the condenser bank to discharge at a precisely controllable firing time, and to uniformly distribute the current flow across the switch thereby reducing the switch inductance. It has been determined that discharges across the gap will occur at the places ionized by the tickler. This is a unique feature of this switch and contributes to its very low inductance and high current carrying capacity.

Now referring to the drawings and more particularly to Fig. 1 there is illustrated an arc gap magneto hydrodynamic switch in accordance with the present invention. As shown, the device includes a coaxial cable transmission line which has an inner electrical conductor 11 and an outer electrical conductor 12 separated by an insulating material 13. Conductor 12 has been opened to form an open circuit and oppositely disposed doughnut shaped electrodes 14 and 15 are secured about the transmission line and connected to the ends of the conductor 12 at the open circuit therein. Electrode 15 is adapted to be adjustable such that the gap between the electrodes can be adjusted in accordance to the voltage used and the desired delay time in permitting a current flow between the electrodes. The electrodes are suitably contoured to reduce ionization which tends to cause pre firing of any type of high voltage gap switch. Electrode 14 is provided with tickler electrodes 16 which have the ends thereof protruding into the air gap with the ends thereof closely adjacent to the conductor 12 so that the tickler spark will jump close to the inside surfaces. The tickler electrodes are formed by coaxial cables 17 equally spaced about the electrode with the outer conductor 18 connected with the electrode 14 and the inner conductor 21 with the insulation thereon passing through the electrode such that the end of the inner conductor extends into the air gap spacing to form the tickler electrode 16.

The gap switch is shown connected with a condenser 22 and a load 23. As shown, the positive side of the condenser is connected with a line to the inner conductor of the coaxial cable and the ground side of the condenser is connected to the outer conductor of the coaxial cable. The supply source (condenser) 24 for the tickler is shown along with a switch 25 for controlling the tickler discharge. The supply to the condensers 22 and 24 is not shown for simplification of the drawings.

In operation, the condensers are charged to their desired or full capacities, then switch 25 is closed to discharge condenser 24 through the tickler electrode. Discharge of condenser 24 produces a spark between the tickler electrode and electrode 14. The tickler electrode has an opposite polarity from that of the opposite electrode 15 in order to minimize delay in initiating the breakdown between the main electrodes 14 and 15, thus, a spark discharge across the opening, ionizes the air between the main electrodes thereby causing the main condenser to arc discharge across the main electrodes.

The arc discharge across the main electrodes produces high temperature electrically heated air, as well as

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metallic electrode vapors in the air gap between the electrodes. The magnetic field, associated with the current through the inner conductor, set up about the gap causes the arc discharge to be forced away from the gap area and prevents damage to the insulating material as well as preventing the insulating material from becoming coated with vapors from the electrodes and shorting out the electrodes. Therefore, there is no deleterious effect on the electrodes, or the insulation on the center conductor, by the hot gas produced by the spark. Such switches can be positioned any place along a coaxial transmission line.

As an example for operation of the switch as shown in Fig. 1, the triggering electrode is supplied by a 0.01 mfd., 75 kv. capacitor and the capacitor bank of 140 mfd. across the switch is charged to 20 kv. developing a current of over 10^6 amperes. A gap spacing of $\frac{3}{4}$ inch would be suitable for this example. Such a capacitor bank is suitable for discharging a high current for use by thermonuclear research devices or any other device which requires high currents and high voltages for operation.

Figs. 2, 3, 4 and 7 are modifications of the device of Fig. 1, suitable for mounting directly onto a condenser. Fig. 2 illustrates the use of an electrode 31 which is electrically connected to the inner conductor 11 and which has a ball shaped end with a skirt that extends down over the insulation 13 toward the doughnut shaped electrode 14. In this modification the outer conductor 12 extends only as far as the doughnut shaped electrode and the circuit is completed across the gap between electrode 14 and the electrode 31 which is secured to the inner conductor 11. Electrode 31 is adapted to be adjustable along the surface of the inner conductor in order to vary the gap distance between the electrodes for control of the discharge. The modification, as shown, includes tickler electrodes 16 as in the device of Fig. 1 and the operation is the same. Connection in a suitable circuit to load is made between the electrode 14 and the ground side of the condenser, the other side of the condenser is connected to the inner conductor of the switch which completes the circuit through electrodes 31 and 14 across the air gap between the electrodes. The tickler discharge circuit is not shown for the purpose of simplification.

Fig. 3 illustrates a coaxial air gap switch suitable for very high voltages as well as a high current. The switch includes an electrode 14 with tickler electrodes as disclosed for Figs. 1 and 2. In this modification the inner conductor 11 is shown extending beyond the electrode 14 but short of the full length of the insulating material. The insulating material between the inner conductor and the electrode is adjustable relative to the electrode 14 and the inner conductor to determine the operating voltage. The longer the spark gap the higher the operating voltage. Thus the inner conductor and electrode could be positioned short of the end of electrode 14 and the insulation just separating the two electrodes. For quicker discharge and at lower voltages the insulation can be adjusted such that the inner conductor extends beyond the insulation, as shown in Fig. 4. Thus, the spark travels almost directly between the electrode 14 and the end of the electrode on the inner conductor.

Figs. 5 and 6 illustrate the use of the principle of operation of the devices of Figs. 1, 2, 3 and 4. Fig. 5 illustrates a device in which the inner conductor extends above the insulation material as shown in Fig. 4 and the arc discharge will be between the inner conductor and the outer conductor positioned at the bottom of an envelope or enclosure 32. Such a device connected to an alternating current such as 110 volts stepped up by a transformer 33 to a higher voltage will provide a good lamp of the fluorescent neon or mercury vapor type. The voltage required would be no higher than the conventional lamp of these types.

Fig. 6 illustrates the same structure as that of Fig. 5

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with the lamp connected to a condenser 34. Such a device will provide a flash lamp when the condenser is discharged into it.

The structure of Fig. 7 illustrates a modification in which the inner conductor 11 extends beyond the insulation and has an electrode 35 secured to the end thereof. The outer electrode 36 extends about the inner conductor in a semi-spherical shape such that the gases will be ionized and blown outward away from the electrodes. Such a device can be used as an ion gun switch to demonstrate a subsurface bomb explosion, as an ionic propulsion mechanism, as a device for driving a turbine and for magnetic driving of a spark into an explosive mixture to set off an explosion.

The device of Fig. 7 can be modified such that the semi-spherical electrode is flattened out perpendicular to the inner conductor. A discharge of such a device will illustrate a surface atomic bomb explosion.

The teaching of the present invention can be carried out for many other uses by slight modification or adaptation of the magnetic field developed about a wire to force the hot gases and metallic vapors away from the insulation. For example, a switch as shown by Fig. 4 can be enclosed in a spherical envelope with the end of the inner conductor at approximately the center of the sphere and by introducing appropriate gas mixture a Stellar model or an air burst model of an atomic bomb can be shown. The shock front produced by a discharge across the electrodes will produce similar temperatures and geometry as the explosions. The switch of Fig. 4 without an envelope can be used as a sputtering device for coating the inside of a container.

A device using the principle of Fig. 2 can be used as a space heater or a heat exchanger by enclosing the switch discharge device in a jacket for the space heater and by passing tubes carrying a liquid through the chamber for the heat exchanger device. Further use of the device can be applied as a high voltage generator. This is carried out by encircling the switch device with a coil. The accelerated ionized gas cuts the magnetic lines of force due to the coil, thereby causing an E.M.F. to be set up across the coil. By using trigger discharges, timing control can be devised to provide frequency control of the current flow.

A gap switch device as shown in Fig. 1 can be adapted to a thermonuclear device by enclosing the switch device in an envelope, positioning a coil about the envelope and admitting deuterium into the envelope. Discharge across the electrodes in the device will create high temperatures to ionize the deuterium gas to produce a plasma and the magnetic field around the inner conductor drives the gas outwardly from the inner conductor at the same time current is applied to the coil to produce a magnetic field about the coil. The magnetic field in the coil compresses the shock preheated plasma toward the center of the envelope. The outward force working against the inward force compresses the gases and a magnetic pumping action occurs which as the resultant of the two magnetic fields increases the temperature to the thermonuclear range.

In operation of the switch devices illustrated, the firing time delay depends on the separation of the electrodes, the operating voltage and the presence of a tickler electrode or electrodes for initiating the discharge. An operating range of the switch can be established wherein the delay time for the switch arc discharge is reduced to 0.1 μ sec. after the tickler discharge. Obviously without the tickler electrode, the firing time will not be closely controllable and the firing time will be irregular; therefore, for quick programmed firing, a tickler discharge is necessary. There are instances when controlled timing is not important and the tickler control of firing can be eliminated in all switches described, by simply increasing the voltage on the main

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discharge across the switch until the switch gap breaks down on its own accord.

Minimum inductance in coaxial transmission lines is achieved by keeping the conductors short and the two conductors as large in diameter as practicable while keeping the intervening insulation as thin as the over voltage safety factor permits.

Due to the coaxial geometry of the gap switches shown, the switches are suitable for enclosure and can be operated as a vacuum switch or as a pressurized switch for the purpose of increasing the high voltage breakdown point for a given gap length.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. An air gap switch device which comprises inner and outer coaxial electrical conductors separated by an insulating material, first and second electrodes secured thereto to provide an open circuit in said switch, said first electrode being secured to said outer electrical conductor and separated from said second electrode to provide an air gap therebetween, said inner conductor extending along said air gap and separated therefrom by said insulating material.

2. An air gap switch device as claimed in claim 1 wherein tickler electrodes are inserted through one of said electrodes with an end thereof protruding into said air gap.

3. A magnetohydrodynamic switch device which comprises coaxial inner and outer electrical conductors separated by an insulating material, first and second electrodes connected thereto to provide an open circuit between said electrodes, said first electrode being doughnut shaped and secured to said outer conductor and separated from said second electrode to provide an air gap between said electrodes, said inner conductor extending along said air gap and separated therefrom by said insulating material.

4. A magnetohydrodynamic switch device which comprises coaxial inner and outer conductors separated from each other by an insulating material, said outer conductor having an open circuit therein with spaced ends, first and second doughnut shaped electrodes secured to said outer conductor at the open circuit therein to provide an air gap between said electrodes, said inner conductor extending along said air gap and separated therefrom by said insulating material.

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5. A magnetohydrodynamic switch device as claimed in claim 4 wherein one of said electrodes comprises tickler electrodes that have an end protruding into said air gap.

6. A magnetohydrodynamic switch device as claimed in claim 4 wherein one of said electrodes is adjustable with respect to the other of said electrodes in order to vary the gap.

7. A magnetohydrodynamic switch device which comprises inner and outer coaxial electrical conductors separated by an insulating material, an open circuit gap between said inner and outer conductors formed by an end of said conductors, first electrode secured to the end of said outer conductor at the open circuit gap, a second electrode secured to the end of the inner conductor at the open circuit gap to provide an air gap between the electrodes, said inner conductor extending along said air gap and separated therefrom by said insulating material.

8. A magnetohydrodynamic switch device as claimed in claim 7 wherein said second electrode has a skirt which extends over said insulation toward said first electrode.

9. A magnetohydrodynamic switch device as claimed in claim 7 wherein said insulation between said outer and inner conductor extends beyond the electrode secured to said inner conductor.

10. A magnetohydrodynamic switch device as claimed in claim 8 wherein said second electrode is adjustable with respect to said first electrode in order to vary the air gap between the electrodes.

11. A magnetohydrodynamic device which includes an envelope having a base, inner and outer coaxial electrical electrodes separated by an insulating material and secured axially within said envelope, said outer electrode being positioned near the base of said envelope, said inner electrode extending along the axis of said envelope to about the center thereof, and said insulation extending along said inner electrode to about the end thereof, said inner conductor extending along said air gap and separated therefrom by said insulating material.

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