

May 24, 1949.

C. DEPEW

2,471,263

IONIC DISCHARGE DEVICE

Filed May 24, 1946

2 Sheets-Sheet 1

FIG. 1

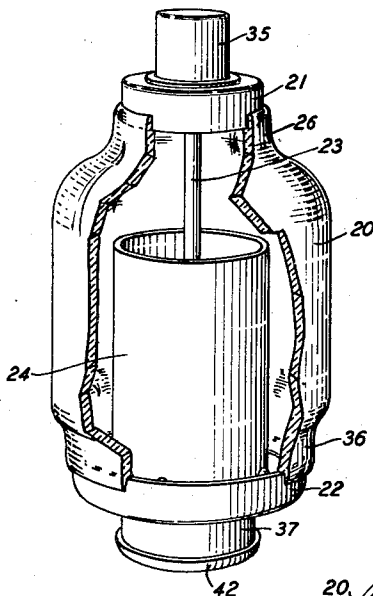


FIG. 2

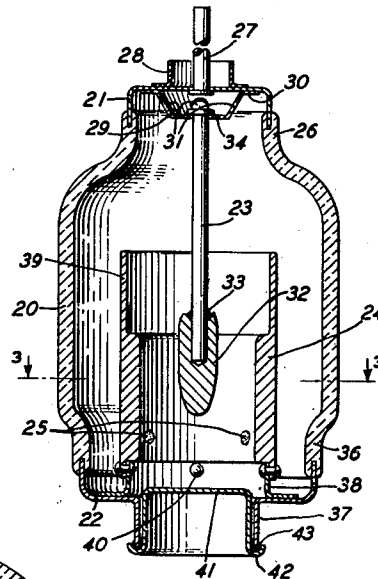


FIG. 3

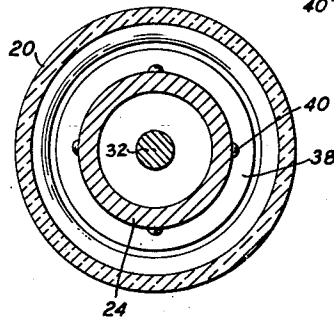


FIG. 4

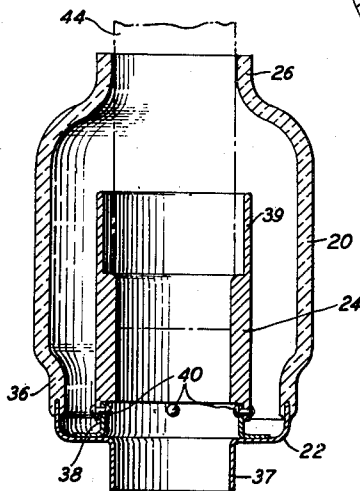
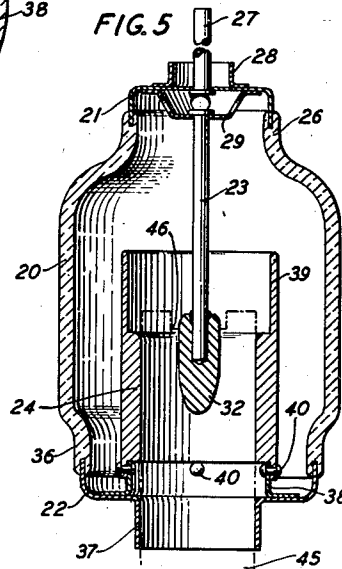


FIG. 5



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FIG. 9

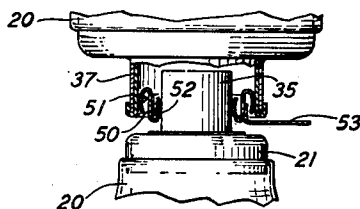


FIG. 7

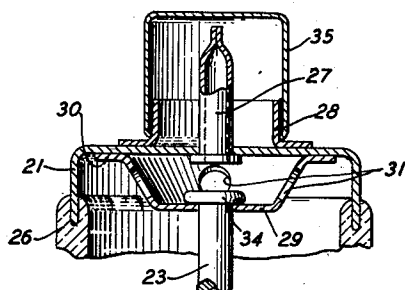


FIG. 10

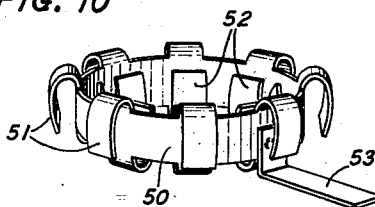
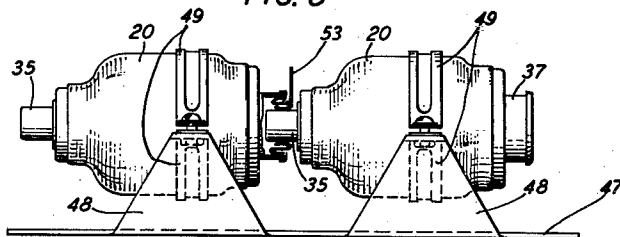


FIG. 8



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2,471,263

IONIC DISCHARGE DEVICE

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Application May 24, 1946, Serial No. 672,010

12 Claims. (Cl. 250—27.5)

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This invention relates to ionic discharge devices and more particularly to high frequency spark gap devices especially suitable for use as pulse generators and capable of handling a high power output.

In high voltage pulse signaling systems employing spark gap discharge devices for generating high frequency pulses of high periodicity, the intense heat generated in the gaps of the individual devices, due to ionization and breakdown at the high rate of discharge, causes sputtering of the electrodes, and particularly the cathode, which eventually shortens the efficient operating life of the devices because of alteration in the critical spacing of the gap between the electrodes.

While sputtering may be minimized by suitable choice of electrode materials, electrode spacing and configuration, gas mixture and pressure and the operating range of the device, a primary fault of prior constructions of the coaxial electrode type is the lack of stable symmetrical relation between the electrodes. Since the discharge occurs over a path of minimum resistance, it is readily seen that eccentricity between coaxial electrodes will produce a preferential path for the discharge at the minimum distance between the electrodes. Consequently, sputtering of the cathode material will be enhanced by displacement of the cathode with respect to the anode of the device. Furthermore, the surrounding cathode, which has the greater mass and surface area of the electrodes in the device, is readily displaced if only supported by a slender conductor sealed through one end of the enclosing vessel. These disadvantages are accentuated when the spark gap discharge devices are subjected to severe usage as a result of shock or vibration such as occurs due to percussion on board naval vessels or in airplanes when landing.

One object of this invention is to insure axial symmetry between the electrodes in spark gap or other conduction discharge devices.

Another object of the invention is to facilitate the fabrication of the device whereby accurate space relation between the electrodes is attained.

A further object of the invention is to overcome shock and vibration conditions which deleteriously affect the static and dynamic characteristics of the device.

Another object of the invention is to prolong the operating life of such devices with high efficiency and increase the power dissipation rating thereof at high output.

Another object of the invention is to simplify the manufacturing procedure of the device.

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Another object of the invention is to improve the rigidity of the electrode assembly in the device so that eccentric space relation between the electrodes is substantially eliminated.

These objects are attained in accordance with features of this invention by an assembly of electrodes in the enclosing vessel involving a cylindrical metallic cathode and an axial solid anode which are coaxially mounted on cup-shaped terminal members hermetically sealed to opposite end portions of the enclosing vessel. This construction eliminates extraneous cemented terminals for the device, facilitates the fabrication and mounting of the electrodes, insures stability in space relation between the electrodes and enhances the operating life of the device by insuring freedom from preferential discharge between the electrodes.

A beneficial feature attending the assembly of the device of this invention relates to the accuracy in critical space relation of the electrodes attained in the fabrication of the device. This desideratum is realized by mounting the separate electrodes on cup-shaped metallic members which are sealed to opposite ends of a hollow cylindrical vitreous vessel in such a manner that accurate concentricity of the cathode and vessel is produced in sealing.

Another feature of the invention relates to the mounting of the cylindrical cathode on its terminal member to insure high rigidity and fixed relation thereof to the anode in the device. This construction involves the provision of an annular flange on the internal surface of the cathode terminal member and rigidly securing the cylindrical cathode thereto in concentric relation to the peripheral sealing rim of the terminal member.

A further feature of the cathode assembly relates to the formation of the cathode terminal member to facilitate the gauging of the anode mounting in the vessel. The cathode terminal member is provided with a coaxial tubular extending portion having the same diameter as the cathode and, after the cathode assembly is sealed to the enclosing vessel, the tubular portion and cathode both cooperate in accurately centering the anode assembly on the opposite end of the vessel. The tubular portion is terminated by an inverted cup closure which seals the cathode terminal member and forms a contact portion for the cathode.

Another feature of the invention relates to the anode construction which facilitates pumping, filling and sealing the vessel in the completion of

the device. This construction includes the mounting of an anode standard concentrically on a perforated platform within the anode terminal member and providing a metallic tubulation at the center of the terminal member which is sealed off after processing the device. The tubulation is enclosed in an extension of the terminal member which is capped with a protective closure and serves as a contact for connecting the device in an operating circuit.

A further feature of the invention relates to the assembly of two devices in series relation for multiple-gap operation in which the anode contact of one device is in telescopic relation with the cathode terminal of another device. This construction includes a circular compression resilient member which engages both the anode contact and the cathode cavity terminal portions of the respective devices when mounted in telescopic relation to insure positive continuity between the devices when connected in series relation.

These and other features and advantages of the invention will be more clearly understood from the following detailed description when considered with the accompanying drawings which show illustrative embodiments of the invention.

Fig. 1 is a perspective view of the complete assembly of a discharge device illustrative of this invention with a portion of the vessel broken away to show the disposition of the electrodes;

Fig. 2 shows in elevation a sectional view of the device of Fig. 1 to illustrate the symmetrical relation of the spark gap electrodes in the vessel;

Fig. 3 is a cross-sectional view of the coaxial electrodes in the vessel taken on line 3—3 of Fig. 2;

Figs. 4 and 5 are cross-sectional views illustrating successive steps in the sealing of the electrode assemblies to opposite ends of the vessel to insure accurate concentricity of the electrodes in the device;

Fig. 6 is a perspective exploded view showing the various component assemblies entering into the fabrication of the device illustrative of this invention;

Fig. 7 is an enlarged cross-sectional view of a portion of the anode assembly of the device illustrating the detailed construction of the seal and the protective closure therefor;

Fig. 8 illustrates an improved mounting assembly of a two-gap combination involving devices of this invention in series relation;

Fig. 9 is an enlarged view of the resilient coupling for the series combination of devices, taken on the line 9—9 of Fig. 8, and illustrating the large surface contact provided by the coupling between the devices; and

Fig. 10 is an enlarged perspective view of the ring contact, shown in Fig. 9, having bent resilient fingers on opposite sides of the ring to provide positive contact with the respective walls of the terminals of the series connected devices.

The discharge device of this invention, in one aspect, is represented as a high voltage-high frequency spark gap pulse generator device capable of supplying a large output of the order of 300 amperes peak current, the construction being sufficiently rugged to withstand severe handling and working conditions without altering the critical gap spacing between the electrodes. These electrodes are subjected to intense ionic discharges at high voltages of the order of 3 to 10 kilovolts and operate in a pulse frequency range of 1,000 to 1,600 pulses per second with a pulse

period of 5×10^{-6} per second. Under these high operating conditions and the intense sparking energy dissipated in the device, to minimize sputtering of the electrodes, it is essential to attain absolute concentricity between the electrodes and maintain such accuracy of space relation throughout the operating life of the device regardless of the severe handling and usage of the device in operational equipment.

In order to attain the high power rating developed by the device illustrative of this invention, the surface area of the cathode is increased to dissipate the heat energy generated in the ionizing atmosphere of the device. The mass of the cathode and its mounting, therefore, must not endanger the critical spacing between the electrodes to insure efficient operation at high pulse periodicity over a long life. If shocks or vibrations are permitted to endanger the concentricity of the electrodes or if the electrodes are initially eccentric with respect to each other, it is readily seen that preferential or spot discharges will occur in the gap between the electrodes at the point of minimum distance between the electrodes and result in short life, due to erosion or sputtering effects of the spot discharges. Such effects alter the space relation of the electrodes with consequent unstable characteristics and degenerative effects upon operation of the device.

The attainment of stability in operating characteristics and a sufficiently rugged construction to withstand severe usage is realized by an assembly as shown in the drawings.

Referring particularly to Figs. 1 to 3, inclusive, the high voltage spark gap device embodies as main components, a vitreous enclosing vessel 20 open at opposite ends, a pair of metallic cap terminal members 21 and 22 closing the ends of the vessel, a rod anode support 23 centrally located in the vessel and supported by the terminal cap 21 and a cylindrical cathode 24 coaxially surrounding the anode and mounted on the cap 22 of the vessel.

The cap terminal members or closures 21 and 22 are preferably formed of a nickel-iron-cobalt alloy having a thermal coefficient of expansivity at 500° C. of 5.71 to 6.21×10^{-6} per degree centigrade, to match the average thermal expansion coefficient of the vitreous bulb or vessel 20, which is formed of a hard boro-silicate glass, such as 7052 glass, commercially obtainable from Corning Glass Company. The cap members are fused into the open ends of the vessel to form hermetically sealed joints therewith which will withstand the temperature ranges of operation of the device without undue strains at the sealed joints and to maintain a stable ionic discharge in the gaseous filling within the vessel. This filling may be composed of a mixture of 75 per cent hydrogen and 25 per cent argon at a pressure of 60 to 70 centimeters of mercury.

Since the discharge is initiated by break-down of the gap between inactive cold electrodes across the ionizing path in the gas mixture, to achieve conduction between the concentric electrodes whereby high current pulse generation is realized, it is desirable to overcome the inherent dielectric resistance in the gap between the electrodes by introducing a free electron ionizing medium in the discharge space to effect conduction at a lower voltage than would be possible without the medium. This sustaining substance, specifically radium bromide, is applied to the inner surface of the cathode in the form of painted spots 25, to provide initial free electrons

in the gap to facilitate ionization and break-down of the discharge gap on starting. The radium bromide is decomposed on heating during the final processing of the device after assembly to provide elemental radium in the gap so that the presence of free electrons is assured. The starting discharge voltage may be of the order of 6 kilovolts, but after initial break-down the operating voltage may be reduced to 4.5 kilovolts, with the pulse frequency attained by a trigger voltage of 8 kilovolts.

The high voltage operation, high current output and high periodicity of pulse generation capable of being attained in the device impose stringent requirements on operation of the device. For example, corona discharge must be minimized in order to prevent premature arcing or prefring of the discharge before the minimum trigger voltage is impressed on the electrodes. Another difficulty engendered in the high voltage operation of the device is sputtering or diffusion of electrode material in the discharge and particularly the cathode or negative electrode which is subjected to the intense spark discharge in the gap. These effects are substantially eliminated or materially inhibited by the construction of the device whereby stable operation is insured and a relatively long useful life is attained. Furthermore, the critical space relation of the electrodes in the discharge gap is maintained constant substantially throughout the life of the device due to the rigid mounting of the electrodes and the absolute concentricity of the electrode spacings so that preferential discharge to a concentrated spot or area of the cathode is eliminated and thereby alteration of the gap spacing is avoided. Also, the device can withstand rough handling and usage without the gap spacing being endangered by shocks or vibrations even on board naval vessels or other carriers subjected to intense percussions.

The configuration of the electrodes, their mounting and fabrication in the enclosing vessel 20 and the constant space relation, whereby the above results are attained in accordance with features of this invention, will now be described with reference to the drawings. The enclosing vessel 20 is provided with a small diameter neck portion 26 which is made comparable to the diameter of the cap closure 21 so that the periphery of the latter can be hermetically sealed to and embedded in the boundary of the glass to form a hermetically sealed union and rigidly anchor the closure to one end of the vessel to serve as the terminal member of the anode. The closure member 21 is provided with a central, outwardly extending metallic tubulation 27 which is surrounded by a metallic flanged sleeve 28 in concentric relation to the tubulation 27. A truncated conical metallic platform 29 having a flanged base 30 is concentrically secured within the closure 21 and is provided with a plurality of circular apertures 31 around the surface, to form communicating passageways from the interior of the vessel 20 to the exhaust tubulation 27. The anode supporting rod 23 extends centrally from the platform 29 and a cylindrical anode plug 32 having a rounded nose is secured to the rod 23 by brazing a ring of high melting point metal 33, such as copper, in a notch formed on the plug at the juncture with the rod. The anode plug 32 is preferably formed of nickel and supported on the standard or rod 23. The latter preferably is formed of steel, the standard being spot-welded to the platform 29 by ring-welding the button

termination 34 on the inner surface of the platform with the standard projecting through a central aperture in the platform. Since the sleeve 28 and platform 29 have a large surface contact with opposite sides of the closure member 21, it is preferable to form these members of a nickel-iron-cobalt alloy, to avoid expansion strains on the glass seal of the neck portion of the vessel.

The tubulation 27 permits the device to be evacuated in the final processing of the assembly and provides means for introducing the desired gas mixture of hydrogen and argon at the predetermined pressure for efficient operation of the device. The tubulation is then sealed off by pinch-welding and a metallic cap 35 is welded over the sleeve 28 to form a protective covering for the tubulation 27 and provide a cylindrical contact for the anode terminal closure of the device. This detailed assembly of the anode construction is shown in Fig. 7.

The opposite end of the enclosing vessel 20 is provided with a large diameter skirt portion 36 which is only slightly smaller than the diameter of the main body portion of the vessel. The cap closure 22 has a diameter comparable to the skirt portion 36 of the vessel so that its peripheral flange may be hermetically sealed to and embedded in the rim portion of the skirt 36 of the vessel, to provide a large surface terminal and metallic closure for the device. The closure is provided with an outwardly extending integral sleeve portion 37 concentric with respect to the flanged seal portion of the cap member. A flanged ring 38, preferably of a nickel-iron-cobalt alloy, is concentrically ring-welded to the inner surface of the closure member 22 and has a diameter slightly larger than the sleeve portion 37 of the closure member, the ring forming a rugged base support for the cylindrical cathode 24. The cathode 24 is preferably formed of aluminum, since this metal has a low diffusion rate in the type of discharge encountered in the operation of the device. The cathode is formed, e. g. machined to have a main cylindrical body portion of sufficient length to substantially enclose the anode plug 32, and a cylindrical skirt portion 39, of larger diameter, to surround the termination of the plug and a portion of the standard 23 supporting the plug, to provide a shield beyond the main discharge area between the electrodes and thereby prevent the extension of the discharge into the surrounding area with consequent blackening of the wall of the glass vessel 20.

The main inner surface of the cylindrical cathode is polished, to provide a high gloss surface, thereby eliminating any burrs or points which might serve as corona points to cause unstable operation in the discharge between the electrodes. The cylindrical cathode is also provided with a thin wall portion adjacent the support ring 38 so that this portion has the same diameter as the external diameter of the ring 38 and the thin portion is rigidly attached to the ring 38 by nickel-iron alloy rivets 40, to insure a substantial mounting of the large mass cathode on the closure member 22. In this arrangement, the internal diameter of the cathode is the same as the diameter of the sleeve extension 37 of the closure member 22. The large sleeve opening in the closure 22 is terminated by a recessed metallic cap 41, preferably of nickel-plated copper, which is mounted in reentrant relation to the sleeve portion 37 and provided with a curved lip 42 which is sealed with a lower melting point solder, such as silver copper alloy 43. The recessed cap 41 forms a socket

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terminal for connecting the cathode to an external circuit. It will be noted that the terminal contacts of the respective electrodes in the device have different configurations and dimensions and are coaxially mounted on opposite ends of the enclosing vessel so that the device can be inserted readily in an operating circuit without error since the terminal configurations of the electrodes are self-indexing and proper connection of the electrodes to their respective voltage sources is assured.

Prior to the assembly of the closure cap members on the ends of the enclosing vessel, the electrodes are individually mounted concentrically on the respective closure members while employing the turned peripheral portion of the cap member as an index for the mounting of the respective electrodes accurately in concentric position with respect thereto. After this operation is completed, the cathode assembly is sealed to the larger diameter end 36 of the enclosing vessel 20, as shown in Fig. 4. A cylindrical jig or gauge 44 is inserted in the small neck portion 26 of the enclosing vessel 20 and the cathode assembly is introduced through the larger diameter end of the vessel 20 so that the gauge fits within the internal diameter of the cathode 24. In this position, the glass skirt portion 36 of the enclosing vessel is heated to render the glass plastic and also to heat the flange portion of the closure member 22 so that the periphery of the cup is embedded in the plastic glass to form a vacuum-tight sealed joint. After this operation is completed and the seal has cooled sufficiently to remove strains, the gauge 44 may be removed. The cathode 24 is accurately centered with respect to the axis and cylindrical wall of the enclosing vessel 20 so that it will always maintain this position in the vessel since the cap member 22 is sufficiently rigid to prevent flexing movement thereof which would alter the relationship of the cathode with respect to the cylindrical surface of the vessel.

The mounting of the anode assembly on the opposite end of the enclosing vessel is shown in Fig. 5, in which another cylindrical gauge 45 is inserted through the sleeve portion 37 of the closure member 22 and the inner surface of the cathode 24. Prior to this operation, the cap closure 41 is not assembled on the sleeve portion 37 of the closure 22 so that this sleeve portion is open and since it has the same diameter as the cathode the gauge 45 will accurately slide into the assembly. The cylindrical gauge 45 is provided with an accurately shaped socket 46 to receive the anode plug 32 which was previously assembled on the terminal member 21 and mounted in position through the neck portion 26 of the enclosing vessel, as shown in Fig. 5. The neck portion 26 is then heated to render the glass plastic and when the proper sealing condition is attained a slight longitudinal movement of the gauge 45 will permit the rim of the closure cap member 21 to be embedded in the neck portion 26 of the vessel, to provide a hermetic seal joint and insure absolute concentricity of the anode with respect to the cylindrical inner wall surface of the cathode. After the gauge 45 is removed, the closure cap 41 is sealed to the sleeve 37 as previously described. The mounting of the large area cylindrical cathode on the short annular support 38 within the cup-shaped terminal member 22 rigidly maintains the cathode in concentric relation to the anode plug 32. The latter is rigidly supported on the standard attached to the cup-shaped terminal member 21 on the oppo-

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site end of the vessel so that constant symmetry is maintained in the discharge gap between the electrodes.

Another feature of the construction of the device in accordance with this invention relates to the mounting of two or more discharge devices in series relation for multi-gap operation, as shown in Fig. 8. The two devices are mounted in series relation on a mounting plate 47 having twin pairs of triangular-shaped walls 48 bent upwardly at right angles to form mounting cradles for the devices. The devices are clamped in semi-circular clamp members 49 attached to the side walls 48 of the mounting with the anode terminal 35 of one device in telescopic relation with the cathode terminal contact 41 of the preceding device. The telescopic union is achieved by a resilient annular compression member, shown more clearly in Figs. 9 and 10. The compression spring member is a metallic ring 50, preferably of beryllium copper. It is formed of a central strip member having a plurality of equally spaced fingers projecting outwardly on opposite sides of the strip, the fingers 51 on one side being bent outwardly and downwardly and the fingers 52 on the opposite side being bent inwardly and upwardly to engage the socket closure cup 41 and the cylindrical terminal 35, respectively, of the contacts of the respective devices in telescopic relation. A strap terminal member 53 may be welded to the annular contact 50 to provide a medial terminal for applying the trigger voltage to the series combination, while the negative side of the high voltage system is connected to the socket 41 of one device and the positive side of the voltage source is connected to the cap terminal 35 of the other device.

While the invention has been disclosed with respect to a particular embodiment of a spark gap discharge device, it is of course understood that various modifications may be made in the assembly which would readily adapt the invention to various other devices of like nature, such as high vacuum condensers, high vacuum switches, mercury vapor rectifiers, trigger control devices and other electronic discharge devices, without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. An ionic discharge device comprising a vitreous enclosing vessel having open ends of different diameters, a metallic cap member sealed to and closing the smaller end of said vessel, a solid anode supported by said member and extending axially within said vessel, an apertured metallic cap member having a central tubular extension sealed to and partially closing the larger diameter end of said vessel, a cylindrical metallic cathode rigidly affixed to said apertured cap member and coaxially surrounding said anode within said vessel, the inner diameter of a portion of said cathode being of the same dimension as the inner diameter of the tubular extension of said apertured cap member, and an inverted recessed closure fitted into said tubular extension.

2. An ionic discharge device comprising a vessel open at opposite ends, an anode and a cathode positioned within said vessel, metallic closure members sealed to opposite ends of said vessel, a metallic perforated platform concentrically secured to one of said closure members, a central post projecting inwardly from said platform, said anode being attached to said post, and a flanged ring concentrically affixed to the other of said closure members within said vessel, said cathode

being carried by said ring and coaxially spaced from said anode.

3. An ionic spark gap discharge device comprising a vessel open at opposite ends, metallic closures sealed to the ends of said vessel, a metallic perforated platform secured to one of said closure members, a central post projecting inwardly from said platform, a solid anode attached to said post, a flanged ring concentrically affixed to said other closure member within said vessel, a cylindrical metallic cathode rigidly mounted on said ring and surrounding said anode, and a recessed cap member in the central portion of said other closure member.

4. An ultra-high frequency spark gap device for high power output operation, comprising coaxially mounted cathode and anode electrodes, a cylindrical vitreous vessel enclosing said electrodes, metallic terminal cap members sealed to opposite ends of said vessel and supporting said electrodes therein, one of said members having a smaller diameter than the other, a sleeve on said smaller diameter member, a coaxial exhaust tube within said sleeve, and a cap carried by said sleeve and protecting said exhaust tube.

5. An ultra-high frequency spark gap device for high power output operation, comprising coaxially mounted cathode and anode electrodes, a cylindrical vitreous vessel enclosing said electrodes, metallic terminal cap members sealed to opposite ends of said vessel and supporting said electrodes therein, one of said members having a larger diameter than the other, coaxial sleeve portions extending from opposite sides of said larger diameter member, said cathode being attached to the inner sleeve portion on said member, and a recessed cap fitted in the outer sleeve portion.

6. An ultra-high frequency spark gap device for high power output operation, comprising coaxially mounted cathode and anode electrodes, a cylindrical vitreous vessel enclosing said electrodes, metallic terminal cap members sealed to opposite ends of said vessel and supporting said electrodes therein, one of said members having a larger diameter than the other, coaxial sleeve portions extending from opposite sides of said larger diameter member, said cathode being attached to the inner sleeve portion on said member, said cathode and outer sleeve portion having the same internal diameter, and a recessed cap fitted in the outer sleeve portion.

7. A high voltage spark gap comprising a vitreous receptacle of cylindrical form having a neck portion at one end, a metallic closure sealed to said neck portion, an apertured platform member affixed to said closure, a central tubulation in said closure communicating with the space in said receptacle through said member, a central standard supported by said platform member, an anode plug projecting from the inner end of said standard, a flanged metallic ring closure

sealed to the opposite end of said receptacle, an internal annular member secured to said ring closure, a cylindrical cathode surrounding said anode and rigidly affixed to said annular member, and a reentrant metallic cap sealed to and closing said ring closure.

8. A mounting comprising a plurality of high frequency spark gap devices arranged in series relation, said devices each having metallic cylindrical and circularly recessed terminal portions at opposite ends thereof, the cylindrical terminal portion of one device being in telescopic relation to the recessed terminal portion of another device, and an annular compression spring member interposed between said terminal portions in telescopic relation.

9. A twin-gap pulse device mounting comprising a pair of spark gap devices in series relation, one of said devices having a protruding anode terminal telescopically fitted into a recessed cathode terminal of the other device, and a resilient member of circular configuration having reversely bent inner and outer fingers engaging the coaxial surfaces of said terminals in telescopic relation.

10. In a spark gap discharge device, an electrode assembly comprising a metallic closure cap sealed to one end of an insulating enclosing vessel, an apertured platform spaced from and supported within said closure cap, a standard rigidly fixed to said platform, and an electrode secured to the free end of said standard.

11. In a spark gap discharge device, an anode assembly comprising a metallic closure cap sealed to one end of an enclosing vessel, a frusto-conical metallic member centrally mounted within the confines of said closure cap, said member having distributed openings adjacent the periphery thereof, and a rod anode centrally affixed to said member.

12. In a spark gap discharge device, an anode assembly comprising an apertured metallic closure cap sealed to one end of a vitreous enclosing vessel, a metallic platform mounted within said cap in concentric relation to the periphery thereof, a projecting tubulation centrally sealed to said cap, an anode supported on said platform, a sleeve on said cap surrounding said tubulation, and a protective cover member closing said sleeve over said tubulation.

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