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TRIGGERED VACUUM GAP DEVICE HAVING FIELD EMITTING TRIGGER ASSEMBLY

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Fig. 1.

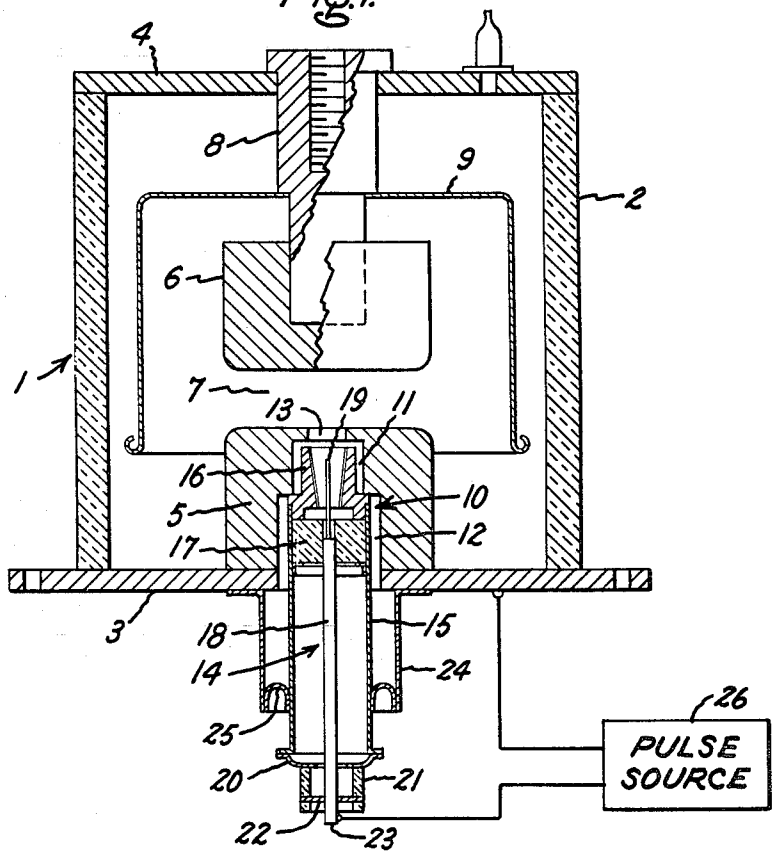
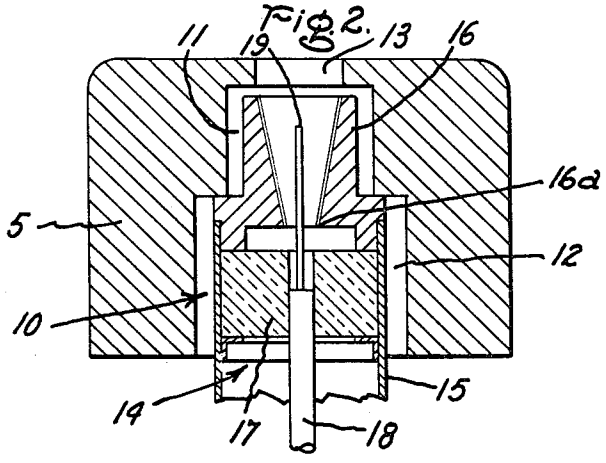


Fig. 2.



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TRIGGERED VACUUM GAP DEVICE HAVING FIELD EMITTING TRIGGER ASSEMBLY

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Application Dec. 28, 1965, Ser. No. 516,943, now Patent No. 3,323,002, dated May 30, 1967, which is a continuation-in-part of application Ser. No. 297,925, July 26, 1963. Divided and this application Sept. 7, 1966, Ser. No. 577,723

2 Claims. (Cl. 313—178)

This application is a division of my copending application Ser. No. 516,943, filed Dec. 28, 1965, now U.S. Patent No. 3,323,002, which is a continuation-in-part of my copending application, Ser. No. 297,925, filed July 26, 1963, now U.S. Patent No. 3,290,542, both of which are assigned to the present assignee.

The present invention relates to improved vacuum gap devices and particularly to such devices which exhibit a unique characteristic of non-degradation of the trigger gap thereof over long periods of use.

Vacuum switches and vacuum gaps with variable and fixed gaps respectively and in various embodiments and modifications have recently become of great commercial significance. In accord with my issued U.S. Patent No. 3,087,092, entitled "Gas Generating Switching Tube," issued Apr. 23, 1963, one very substantial detriment to the wide application of vacuum gap devices, namely the unpredictability and unreliability of breakdown voltages and the time of breakdown (or jitter) has been overcome. This has been accomplished by the provision of a separate trigger electrode assembly which injects a pulse of ion-electron plasma into the primary gap to cause the breakdown thereof upon the provision of a triggering pulse to a secondary or trigger gap.

While devices constructed in accord with my aforementioned patent have overcome the greatest impediment to wide usage of vacuum gaps, many of these devices utilize a trigger gap which is, in essence, a pair of metal ceramic interfaces separated by a ceramic gap as the trigger gap thereof. Such a trigger gap is highly advantageous in that the field configuration in the vicinity of a metal-ceramic interface is highly favorable for low voltage breakdown and such a gap may predictably and repetitively be broken down with the application of a low voltage thereto. Such a gap, however, is susceptible to deterioration with usage, in that metallic particles from the main arc between the primary electrodes may become deposited thereupon and lower the dielectric strength of the trigger gap.

Accordingly it is an object of the present invention to provide improved triggerable vacuum gap devices suitable for continuous and long-life operation without any appreciable deterioration of the trigger gaps thereof.

Another object of the present invention is to provide triggerable vacuum gap devices having reliable and repeatable breakdown characteristics in response to a voltage signal, which gaps do not include a trigger gap subject to deterioration by the deposition of metallic particles thereon.

Yet another object of the present invention is to provide triggerable vacuum gap devices having trigger gaps which rely upon field emission for the provision of a triggering pulse to breakdown the primary gap.

In accord with the present invention a triggerable vacuum gap device includes an evacuable envelope containing therein a pair of arc-electrodes defining a vacuum gap. At least one of the arc-electrodes contains a central cavity connected with the arcing face thereof with an aperture. Immediately within the aperture I provide a trigger electrode assembly including a central trigger

electrode of small diameter and substantial length surrounded coaxially with a tapering concentric electrode member which terminates in a field concentrating ring surrounding the trigger electrode at a distance far removed from the aperture into the main gap. The application of a triggering pulse between the central electrode and the surrounding trigger electrode causes field breakdown between the aforementioned ring and the adjacent portion of the central trigger electrode. Vacuum breakdown occurs, a plasma is formed and a burst of plasma is injected through the aperture into the main gap to cause the breakdown thereof. This breakdown is repetitive and the gap may be broken down under substantially identical conditions an indefinite number of times. Additionally, since there is no contaminable ceramic surface immediately adjacent the trigger gap, deterioration thereof due to deposition of metallic particles thereon is avoided, thus increasing the useful life of the trigger gap and of the device under all circumstances of use.

The novel features characteristic of the present invention are set forth in the appended claims. The invention itself, however, together with further objects and advantages thereof may be more readily understood by reference to the appended drawing in which:

FIGURE 1 is a vertical cross-sectional view of a triggerable vacuum device constructed in accord with the present invention; and

FIGURE 2 is a vertical cross-sectional view of the trigger electrode utilized in the device of FIGURE 1.

In FIGURE 1 of the drawing a vacuum gap device having a pair of fixed electrodes constructed in accord with the invention includes an evacuable envelope **1** including an insulating cylindrical sidewall **2** and a pair of apertured metal end closures **3** and **4**. A pair of primary arc-electrodes **5** and **6** are disposed within envelope **1** and define therebetween a gap **7**. Anode arc-electrode **6** is suspended within envelope **1** by anode support member **8** which is suitably fastened in an hermetic seal to metallic end wall plate **4**. A suitable metallic shield member **9** is also connected to anode support member **8** and suspended therefrom so as to laterally encompass the primary gap **7**. Cathode arc-electrode **5** is in the form of a hollow cylindrical member having a cavity **10** along the axis thereof which cavity is composed of a first, smaller-diameter, deep counterbore **11** and a second, larger-diameter, shallow counterbore **12**. Cavity **10** is connected to the gap **7** between arc-electrodes **5** and **6** by means of a central aperture **13** in the arcing face of arc-electrode **5**. A trigger electrode assembly **14** is disposed centrally within cavity **10** and is oriented so as to project an ionized electron-ion plasma through aperture **13** into gap **7** to cause the device to become conducting thereacross.

Trigger electrode assembly **14** comprises a suitable metallic cylindrical member **15** which encloses at one end thereof a generally cylindrical outer trigger electrode member **16** having inverted frusto-conical bore therein which is widest at the inwardly depending end and narrowest at the outwardly depending end **16***a* thereof. Also included within cylindrical member **15** is an insulating ceramic disc **17** located substantially outwardly from the most constricted region of the frusto-conical interior surface of trigger electrode member **16** and abutting against an outwardly depending annular flanged portion thereof. A metallic trigger electrode support member **18** extends through a central aperture in disc **17** and supports an inner, axially located trigger electrode member **19** which passes concentrically into the frusto-conical cavity formed within the outer trigger electrode member **16** and is terminated slightly short of the most inwardly depending surface thereof. The exterior outwardly depending end of

trigger electrode support member **18** extends through a first, cupped and apertured seal member **20** which is bonded in an hermetic seal to a hollow cylindrical ceramic insulating member **21** and hermetically sealed through a trigger electrode end plate **22** which is also hermetically sealed to ceramic cylinder member **21**. A protruding trigger electrode lead **23** extends outwardly from the seal assembly. Cylindrical trigger assembly support cylinder **15** is rigidly supported and hermetically sealed within the aperture in end wall plate **3** of envelope **1** by a pair of suitable sealing flanges which are annular in shape and are illustrated at **24** and **25**.

Cylindrical sidewall member **2**, apertured ceramic disc **17**, and cylindrical seal disc **21** may all be fabricated from a suitable high temperature, gas-impervious ceramic material which is conventionally used in the fabrication of devices of this general class. Thus for example these materials may be fabricated from Coors–V–200 or American Lava–T–164 ceramics. Alternatively a suitable forsterite ceramic may be utilized. End wall members **3** and **4** may conveniently be fabricated from stainless steel, nickel, or titanium parts which are adaptable for sealing by hermetic seals to the chosen ceramic bodies. Primary electrodes **4** and **6** are fabricated from high purity, gas and gas-forming impurity-free copper, or other suitable high vapor pressure material suitable for vacuum switch and vacuum gap application, and should be sufficiently pure as not to contain any more than 10^{-7} atomic parts of gas or gas-forming impurities. Similarly, this material must be sufficiently pure as to gas and gas-forming impurities so that under repeated arcing conditions quiescent pressure within the device after sealing does not rise above a value of 10^{-5} mm. of Hg. Such material may readily be formed by a suitable zone-refining process such as is described and claimed in the copending application, Ser. No. 146,245, filed Oct. 19, 1961, now U.S. Patent No. 3,234,351, of M. H. Hebb and assigned to the assignee of the present invention.

First trigger electrode **16** may conveniently be fabricated from molybdenum with the inner surface of the frusto-conical counterbore therein coated with a thickness of a few mils of titanium or titanium hydride, or any active gas storing substance which may take on an active gas, for example hydrogen, and maintain it under non-operating conditions so as to allow a hard vacuum of 10^{-5} mm. of Hg pressure or less to be established and maintained, but, when subjected to the high temperature of the footpoint of an electric arc, to evolve the active gas, as for example hydrogen. Once this gas is evolved, it is ionized to form a pulse of electron-ion plasma which is injected into the primary gap to cause the breakdown thereof. Centrally located trigger electrode **19** may conveniently comprise a tungsten or molybdenum or a tungsten-rhenium thoria alloy (73% tungsten, 25% rhenium, 2% thoria). Rhenium adds ductility to the tungsten and thoria lowers the work function to aid full emission. The electrode conveniently may be fabricated of approximately 10 mils diameter wire and may be supported upon a substantially thicker molybdenum support member **18**. Seal flanges **20**, **24**, and **25** and end cap **22** may all conveniently be fabricated from Ceramaseal, Fernico, Kovar or other suitable materials well adapted for forming ceramic-to-metal seals.

Assuming that the device of FIGURE 1, which has only one trigger electrode assembly, is to be connected in a protective circuit across a uni-directional high voltage line, it is predictable that the arc-cathode will be arc-electrode **5** and only one trigger electrode need be provided and that is, therefore, located within cathode arc-electrode **5**. If the device were to be utilized with an alternating current system, then a similar electrode assembly **11** would be also disposed concentrically within arc-electrode **6**. For DC operation, the vacuum arc device is connected between the line voltage with the anode electrode **6** connected to the positive polarity through support member **8** and the cathode electrode **5** connected to the negative potential through end plate **3**. A voltage pulse is supplied to trigger electrodes **16** and **19** from pulse source **26** through lead **23** and end plate **3**.

The operation of the trigger gap is substantially as follows: With the high voltage connected between the arc-electrodes **5** and **6**, a high intensity electric field exists within gap **7**. Because of the high dielectric strength of the vacuum this high intensity electric field is insufficient to cause breakdown of the gap and the device remains non-conductive. When a fault in a transmission line occurs or when it is desired to discharge a capacitor bank or for any other reason the device is to be activated, a pulse is applied to inner trigger electrode **19** which is negative with respect to outer trigger electrode **16**. When this occurs, an initial breakdown occurs across the interior, smaller-diameter end of the truncated conical bore within electrode member **16** and the thoriated tungsten or tungsten alloy wire. The small diameter of the wire and the close spacing between the wire and the surrounding circular discontinuity **16***a* in the first electrode member produces an electric field at the surface of the wire equal in magnitude to nearly 50 times the applied voltage pulse. Under these circumstances breakdown of a main gap voltage of approximately 30,000 volts applied to a ⅛ inch gap between ¾ inch diameter electrodes may readily be achieved with a pulse voltage of the order of 7 kilovolts. The initiation of the first breakdown is facilitated by the use of a thoriated tungsten wire as the cathode of the trigger gap since this lowers the work function of the cathode and increases the field emission therefrom. A glow discharge is rapidly established between the trigger cathode **19** and the trigger anode **16**. Since the trigger anode is coated with a material which stores an active gas such as hydrogen, which material may conveniently be titanium hydride, the heat of the footpoint of the initial arc immediately causes the liberation of hydrogen molecules which are rapidly ionized, to further increase the arc current and the temperature of the arc footpoint, the culmulative effect being the creation of a large cloud of hydrogen ion-electron plasma which is propagated by magnetic forces out of the trigger electrode, through aperture **13** in arc-electrode **5** and into the main or primary gap causing the immediate breakdown thereof and the establishment therein of a high current, high voltage electric arc.

A disadvantage with prior art devices has been associated with the use of a grooved surface coating of titanium or equivalent upon a ceramic insulating disc or cylinder. There is always some leakage resistance between the opposite electrodes of such a gap, which resistance may vary from 100 to 10,000 ohms. In general this resistance is caused by minute deposits of metallic particles which are propagated to the insulator of the gap from the main gap during arcing. Although this leakage does not affect the operation or performance of the trigger and does not lower the breakdown resistance of the main gap, it proves in some cases to be a limiting factor upon the type trigger circuits which may be utilized in conjunction with such devices, since the charge on a capacitor may not be retained when connected directly across such a high resistance leakage path. In accord with the present invention, however, I avoid this difficulty by providing a breakdown gap in the trigger electrode assembly which is over a space unoccupied by any physical substance and which is actually a vacuum gap also. Any metallic materials which are propagated down into this gap do not deposit upon an intervening ceramic or other insulating material but rather are usually deposited upon one or the other of the trigger electrodes, those few which do pass through the gap generally being deposited upon the inwardly depending end of trigger support member **18** or the immediately surrounding portions of insulating disc **17**, which in no way affects the resistance between the trigger electrodes.

While the invention has been disclosed hereinbefore with respect to a single trigger electrode it has been mentioned that for alternating current operation a pair of trigger electrodes may be associated respectively one with each of the primary arc-electrodes. Under such circumstances a separate pulse source may be associated with each trigger electrode or a grounded source may be connected to both trigger electrodes and, with the line conductors which are connected to the respective primary gaps having a particular relationship to ground potential an electric arc with occur within the trigger electrode which is associated with the most positive of the line conductors. Similarly this invention may be practiced with devices having movable primary arc-electrodes as well as fixed.

Furthermore, while the invention has been described hereinbefore with respect to certain embodiments and features thereof, many other modifications and changes will no doubt occur to those skilled in the art. Accordingly, it is intended by the appended claims to cover all such modifications and changes as fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a triggered vacuum discharge device enclosed in an evacuated envelope and having a primary discharge gap, the improvement comprising field emitting trigger means for establishing initiation of a primary discharge across said primary gap comprising:

(a) a first elongated trigger electrode in said envelope;

(b) a second cylindrical trigger electrode in said envelope surrounding said first electrode longitudinally along its length to define therewith a field emitting trigger gap;

(c) said second electrode having an interior surface composed of a gas storage metal having an active ionizable gas stored therein so that said gas is liberated upon initiation of a trigger discharge between said trigger electrodes; and

(d) terminal means for applying a triggering signal between said first and second trigger electrodes to initiate a field emission discharge therebetween.

2. In a triggered vacuum discharge device enclosed in an evacuated envelope and having a primary discharge gap, the trigger means of claim **1** wherein

(a) one of said first electrodes is adjacent said primary gap;

(b) said first electrode is connected at its outboard end to said terminal means; and

(c) said second trigger electrode is in the form of a hollow member having an inwardly tapered frustoconical inner surface terminating in a circular discontinuity having a sharply defined point concentrically surrounding said first electrode and defining therewith a constricted field emitting vacuum trigger gap.

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