United States Patent

[11] 3,612,937

[72] Inventors **Sergei Alexandrovich Smirnov ulitsa Pavilika Morozova 1, kv. 15; Ivan Ivanovich Aksenov, prospekt Kurchatova 13, kv. 18; Vladimir Konstantinovich Bocharov, proezd Evpatoriisky 1, kv. 18, all of Kharkov, U.S.S.R.**

[21] Appl. No. **864,579**
[22] Filed **Oct. 8, 1969**
[45] Patented **Oct. 12, 1971**

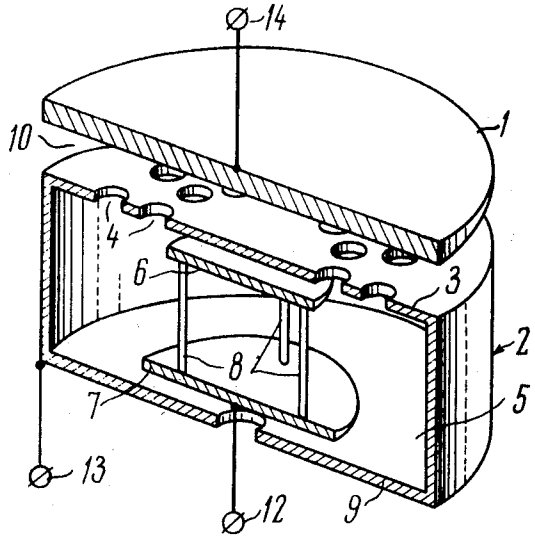
[54] **LOW-PRESSURE CONTROLLED DISCHARGE DEVICE WITH TRIGGER ELECTRODE WITHIN HOLLOW CATHODE**
3 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** ..... **313/197,** 200/144 B, 313/198, 313/217
[51] **Int. Cl.** **H01j 17/00**
[50] **Field of Search** ..... 313/188, 198, 216, 217, 197; 200/144 B

[56] **References Cited**
UNITED STATES PATENTS
3,328,632 6/1967 Robinson ..... 313/198 X

Primary Examiner—Raymond F. Hossfeld
Attorney—Waters, Roditi, Schwartz & Nissen

ABSTRACT: A discharge device comprises an anode, a hollow cathode with apertures on a side facing the anode and a trigger electrode disposed within the hollow cathode. The trigger electrode is constituted as two plates with interconnecting conductive posts one of the plates being disposed at the side of the cathode with the apertures, the other plate being disposed at the opposite side of the cathode. The hollow cathode has a linear dimension between sidewalls at least several times greater than the size of the main discharge gap between the anode and the cathode. The plate of the trigger electrode which is disposed at the side of the cathode with the apertures may be placed in one of such apertures so as to lie in a common plane with the side of the cathode.



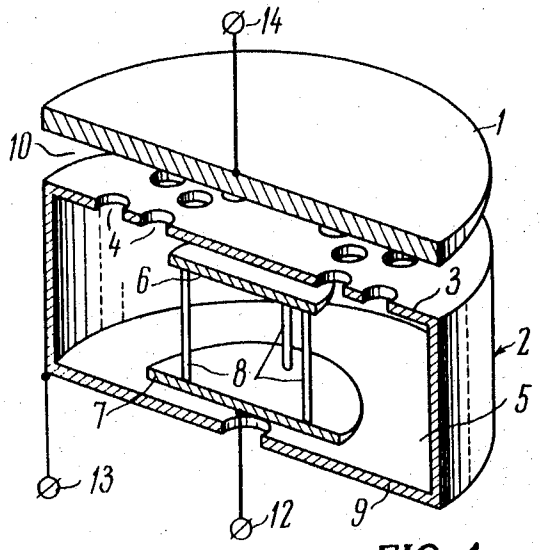


FIG. 1

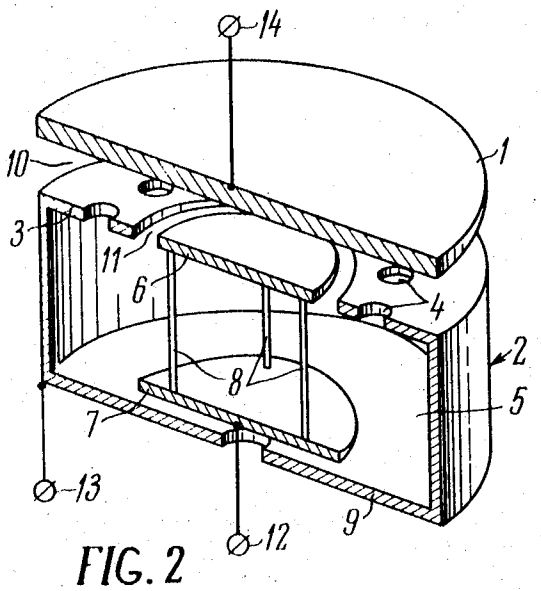


FIG. 2

LOW-PRESSURE CONTROLLED DISCHARGE DEVICE WITH TRIGGER ELECTRODE WITHIN HOLLOW CATHODE

The present invention relates to low-pressure controlled discharge devices capable of passing heavy pulse currents and designed for operation as switching and protection elements in high-voltage installations.

The most perfect discharge devices designed for the above-mentioned purposes are those which are triggered with the help of an auxiliary impulse arc excited in the firing arrangement such as a coaxial plasma gun mounted on the cathode. A disadvantage of such devices is long recovery time determined by the rate of absorption of the hydrogen which is evolved by the electrodes of the firing arrangement in the course of firing. This limits the use of such discharge devices to applications on which they operate infrequently (single operations).

There also exist discharge devices filled with gas or vapor at low pressure, containing a flat anode, a cathode chamber separated from the anode by a perforated or slotted disk which functions as a cathode, and a trigger electrode in the form of a thin disk arranged inside the cathode chamber.

During operation of the discharge device a glow discharge (a radiofrequency discharge, for example) is constantly maintained inside the cathode space. The device is triggered by the application of a negative voltage pulse to the trigger electrode.

In contrast to the discharge devices mentioned before, such dischargers can be used both for single operations and for repeated operation at a high rate. The disadvantage of such devices is the need for a glow discharge in the cathode chamber.

The absence of the glow discharge markedly affects the starting characteristics of the discharge device. Simultaneously, the firing lag and the jitter time increase. Besides, the fact that such devices can be triggered only by negative pulses imposes certain limitations on the trigger pulse circuit.

An object of the present invention is to provide a controlled discharge device free from the disadvantages mentioned above with a smaller amplitude of the trigger voltage, smaller firing lag and jitter time, simple construction and provisions for operation within a wide range of operation rates and currents and voltages to be handled.

With this object in view, in the low-pressure controlled discharge device comprising a hollow cathode with apertures on the side facing the anode and a trigger electrode arranged inside the cathode space, said trigger electrode according to the invention, is in the form of two plates interconnected by conductive posts, one of the plates being arranged at the cathode wall facing the anode the other plate at the opposite wall. With such arrangement the entire trigger electrode is shielded by the cathode walls.

The trigger electrode plate facing the anode may be exposed by arranging it directly in a cathode aperture. In this case the aperture has the shape of the plate and the aperture size is such that a uniform gap is formed between the edges of the plate and of the aperture, the size of the gap being not in excess of the gap between the anode and the cathode.

The present invention makes it possible to design a cold cathode discharger superior in its starting characteristics to the existing devices of a similar type and almost equal in this respect to hot cathode devices (thyratrons). On the other hand, the possibility of designing a discharge device with a current rating not limited by the emission properties of the cathode and with starting characteristics almost on a par with the characteristics of thyratrons holds much promise.

The invention itself, its advantages, objects and possible embodiments will be best understood from the following description when read in connection with the accompanying drawings, in which:

FIG. 1 is a perspective view partly broken away and in section of the discharge device, according to the invention;

FIG. 2 is a similar view showing a modification of the discharge device with an exposed trigger electrode.

Referring to FIG. 1, the discharge device comprises an anode 1 in the form of a disk, a cathode 2 in the form of a hollow cylinder with apertures 4 on a cylinder side 3 serving as a cylinder base facing the anode 1. Arranged inside space 5 of the cathode 2 is a trigger electrode made up of two parallel plates 6 and 7 which are interconnected by conductive posts 8. The plate 6 is mounted near the wall 3, and the plate 7 is mounted near an opposite wall 9 which serves as the second base of the cylinder. The plate 6 of the trigger electrode can be mounted directly within the region of a main discharge gap 10 as shown in FIG. 2 and arranged in the same plane as the side 3. In this case one of the apertures on the side 3 is shaped to fit the plate 6 and the aperture size is such that a uniform gap 11 is formed between the edges of the aperture and of the plate.

The discharge device shown in FIG. 1 operates as follows. In the initial condition a high voltage is applied between the anode 1 and the cathode 2. The spacing between the anode and the cathode and the pressure inside the discharge device are selected so that the conditions for the breakdown of the discharge device should correspond to the left-hand branch of the Pacshen's curve and provide the necessary electrical strength of the discharge device. The effect of the apertures 4 on the electrical strength may be neglected as their diameter is smaller than the width of the gap 10, and the anode field extends but slightly into the space 5. No field is present inside the space 5 before the arrival of a trigger pulse. When a trigger pulse is applied to the lead 12 of the trigger electrode, the field appearing inside the space 5 is distributed in a manner typical for discharge gaps with a hollow cathode and anode. It is well known that due to the "hollow cathode" effect in such systems a self-maintained discharge is initiated and maintains itself at a much lower voltage than in discharge gaps with conventional solid electrodes. The discharge plasma filling the space 5 is an effective source of electrons captured by the anode field through the apertures 4. The number of electrons within the zone of the apertures 4 where they are captured by the anode field additionally increases due to the exposure of the aperture edges to the intensive ultraviolet radiation from such a powerful source as the discharge plasma in the hollow cathode. On its way from the apertures 4 to the anode 1 the stream of electrons ionizes the molecules of the working gas and causes the breakdown of the discharger. After the breakdown, depending on the characteristics of the external circuit either a dense glow discharge is sustained between the anode 1 and the inner surface of the cathode 2 through the apertures 4 or a vacuum arc discharge is sustained between the anode and the outer surface of the side 3.

The trigger pulses for the discharge device described above have a comparatively low magnitude of about 1 to 2 kv. over the entire range of the operating anode voltages (from several hundred volts to some maximum value determined by the electric strength of the main discharge gap 10). With appropriate pressure and appropriate width of this gap the discharge device can withstand voltages up to about 40 kv. It should be, however, noted that the discharger with the electrodes designed as shown in FIG. 1 has a somewhat asymetrical starting characteristic, i.e. positive trigger pulses must have a somewhat greater amplitude than negative trigger pulses. This is particularly noticeable when the width-to-depth ratio of the apertures 4 is small, as is the case when the side 3 has a large thickness as, for example, in discharge devices designed to handle large power.

To improve the starting characteristic with positive trigger pulses the modification of FIG. 2 is preferable. The discharge device embodied as shown in this figure can be triggered equally well by both positive and negative pulses. This is explained not only by the fact that the two electrodes which participate in the initiation of the discharge in the trigger chamber 5 (the cathode and the trigger electrode) have hollow construction and, therefore, the conditions for firing the discharge in the space may be considered to be independent of the polarity of the trigger pulse as in the first case; the addi-

tional explanation lies in the fact that the conditions for the transfer of the discharge into the main gap are independent of the polarity of the trigger pulse since both the cathode and the trigger electrode are disposed within the zone of the direct electrostatic interaction with the anode, which distinguishes this modification from the discharger shown in FIG. 1 wherein both plates of the trigger electrode are shielded from the anode field by the cathode walls. In other words, the cathode and the trigger electrode are, as it were, under similar conditions with respect to the anode. This is also borne out by the fact that the starting characteristics of the discharge device do not change when its connection is modified so that the trigger pulse is applied to a lead **13** and the high voltage, between the lead **12** and an anode lead **14**, i.e. so that the plates **6** and **7** function as a cathode and the cathode **2** functions as a trigger electrode.

However, when selecting the design of the discharge device, it should be remembered that in discharge devices with an exposed trigger electrode the edges of the plate **6** are appreciably affected by the erosion caused by the powerful arc discharge in the area of the gap **11**.

When designing discharge devices according to the present invention it will be well to remember the following points. The linear dimensions of the space **5** must be at least several times greater than the width of the main discharge gap **10** in order that the conditions for firing a discharge in the space **5** must correspond approximately to the minimum of the Paschen's curve. The diameter of the apertures **4** and the width of the gap **11** (FIG. **2**) must not exceed the width of the gap **10** between the anode and the cathode. When selecting the type of gas or vapor the primary consideration must be given to their electrical and chemical properties and to the convenience of maintaining their pressure constant. In this respect the most convenient gas is hydrogen which can be maintained at a constant pressure with the help of a hydrogen generator (source) widely used in, pulse-type hydrogen thyratrons. Naturally, other gases, such as inert gases, or mercury vapors may be used as well.

In both modifications of the discharge device (FIGS. **1** and **2**) a keep-alive discharge may be used at currents from fractions of a milliampere to several milliamperes to reduce still further the firing lag and the jitter time.

The discharge device described herein safely withstood the following test conditions: anode voltage—from several hundreds volts to 35 kv.; the rectangular pulse amplitude of the controlled current—up to 2.5 kA; pulse duration—3 microsec., pulse repetition rate—from 50 to 100 c.p.s.

In single operations the discharge device switched currents as high as 100 kA at the oscillatory discharge of a 10-microfarad bank of capacitors. The oscillation period was approximately equal to 20 microsec. With the trigger pulse amplitude of 2 kv. the firing lag was about 0.5 microsec., the jitter time, about 0.02 microsec.

All these data testify to the obvious advantages of the discharge device described herein over the existing types as regards the starting characteristics and the possibility of operation under various conditions.

The modifications of the discharge devices shown in FIG. **1** and **2** are not the only possible embodiments of the present invention. Apparently, the shape of the discharge device may be other than cylindrical. The electrodes of the discharge device may have rectangular shape convenient for plane-parallel bussing, the apertures **4** may be shaped as slots and the anode may be made from a liquid metal (mercury, gallium, etc.).

The internal space of the cathode as well as the inward surface of the plates **6** and **7** may be coated by an activating layer.

The present invention can be also employed in designing low-pressure H.V. dischargers in which a high electrical strength is achieved by separating the discharge gap between the anode and cathode into several sequential gaps with the help of additional electrodes.

What is claimed is:

1. A low-pressure controlled discharge device comprising an anode, a hollow cathode adjacent said anode and including a sidewall facing said anode and defining a main discharge gap therebetween, said cathode including an opposite sidewall remote from said anode, said sidewall of the cathode facing the anode being provided with apertures, and a trigger electrode disposed inside said hollow cathode and constituted as two plates with interconnecting conductive posts, one of said plates being disposed at said sidewall of the cathode with the apertures, the other plate being disposed at said opposite sidewall of said cathode, said hollow cathode having a linear dimension between said sidewalls at least several times greater than the size of said main discharge gap between the anode and cathode.

2. A low-pressure controlled discharge device as claimed in claim **1**, wherein said plate of the trigger electrode at said wall of the cathode facing the anode is arranged in one of said apertures in the latter sidewall of the cathode, the size and shape of said one aperture being such that a uniform gap is formed between the edges of said plate and said one aperture, the latter gap being smaller than the main discharge gap.

3. A low-pressure controlled discharge device as claimed in claim **1**, wherein said apertures have a diameter smaller than the size of said main discharge gap.