Oct. 8, 1968 KIYOTAKA WASA ET AL 3,405,300

GAS FILLED COAXIAL TYPE ELECTRIC SWITCH WITH MAGNETIC FIELD CUT-OFF

Filed Dec. 29, 1965 2 Sheets-Sheet 1

FIG. 1a

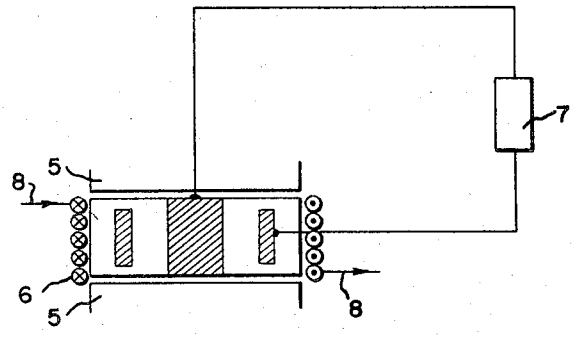


FIG. 1b

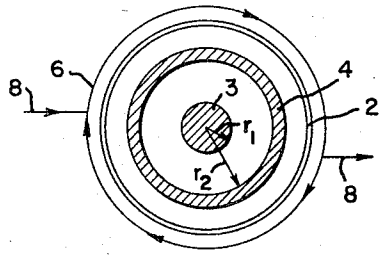
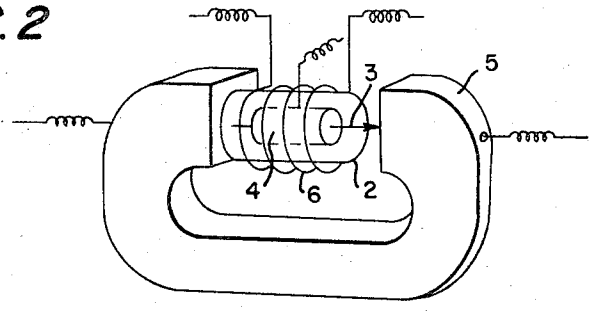


FIG. 2



INVENTORS
KIYOTAKA WASA
SHIGERU HAYAKAWA

BY Wenderoth, Lind & Ponack

ATTORNEYS

Oct. 8, 1968 KIYOTAKA WASA ET AL 3,405,300
GAS FILLED COAXIAL TYPE ELECTRIC SWITCH
WITH MAGNETIC FIELD CUT-OFF
Filed Dec. 29, 1965 2 Sheets-Sheet 2

FIG. 3

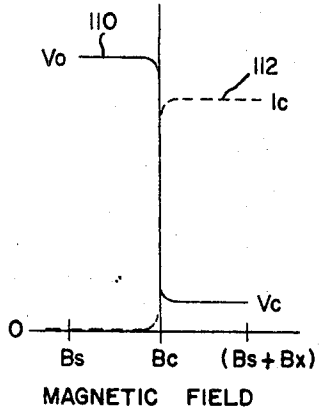


FIG. 4

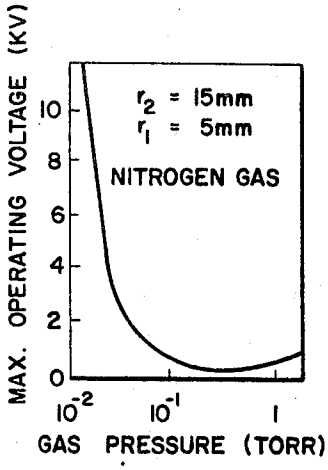


FIG. 5

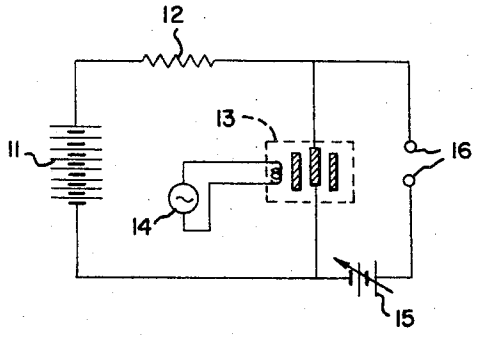
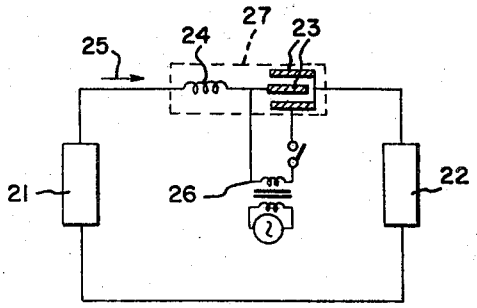


FIG. 6



INVENTORS
KIYOTAKA WASA
SHIGERU HAYAKAWA

BY Wenderoth, Lind & Ponack

ATTORNEYS

United States Patent Office

3,405,300

Patented Oct. 8, 1968

3,405,300

GAS FILLED COAXIAL TYPE ELECTRIC SWITCH WITH MAGNETIC FIELD CUT-OFF

Kiyotaka Wasa, Osaka-shi, Osaka-fu, and Shigeru Hayakawa, Hirakata-shi, Osaka-fu, Japan, assignors to Matsushita Electric Industrial Co., Ltd., Osaka, Japan

Filed Dec. 29, 1965, Ser. No. 517,345

Claims priority, application Japan, July 7, 1965, 40/40,663

3 Claims. (Cl. 313—161)

ABSTRACT OF THE DISCLOSURE

An electric switch of the coaxial cylinder type. It has a pair of cylindrical electrodes which are enclosed in a gas tight envelop, there being an outer cylindrical electrode and an inner cylindrical electrode surrounded at least partially by said outer cylindrical electrode. One of said pair of cylindrical electrodes is a cold cathode and the other of said pair of cylindrical electrodes is an anode. The envelope is filled with an ionizable medium at a pressure which is less than λ_0/r_2-r_1 torr, where λ_0 is the mean free path of an electron at 1 torr and r_1 and r_2 are the radius of said inner and outer electrode, respectively. A magnet means is provided adjacent the outside of said envelope and consists of a permanent magnet and a coil superposing a magnetic field between said electrodes in a direction transverse to the spacing of said electrodes. As a result, the electric switch closes an electrical circuit across the space between said electrodes when there is superposed thereon a magnetic field more than an electron cut-off field Bc, and opens said electrical circuit across the space between said electrodes when the superposed magnetic field is less than said electron cut-off field Bc.

This invention relates to a device for an electric switch which can operate at a high speed, and more particularly to a switch which can be used in a high voltage circuit. Furthermore it relates to such a device which acts as an over-current switch having means controlling the following current therein.

Ignitrons or thyratrons are representative tubes of the kind now in use as high speed switches in electric circuits. The former are essentially diode discharge tubes with control-electrodes and an igniter sealed therein. The latter are essentially triode discharge tubes containing a control grid. These control electrodes are made with special care and moreover they are exposed to a discharge when the tube is in a closed circuit. Therefore, they are easily and often damaged. Thus, considerable caution is required to increase the operable life thereof.

An object of this invention is to eliminate these drawbacks and to provide a novel high speed switch with long life for use in a high voltage circuit.

Another object of the invention is to provide a high voltage pulse generator with a simple circuit.

A further object of the invention is to provide an over-current circuit breaker which operates at high speed.

Further features and advantages of the invention will appear from the following description of a presently preferred species thereof.

In the accompanying drawings:

FIGS. 1*a* and 1*b* are an axial section and transverse section, respectively, of the device of the present invention;

FIG. 2 is a perspective view of an embodiment of the device of FIGS. 1*a* and 1*b*;

FIGS. 3 and 4 are graphs illustrating the static characteristics thereof;

FIGS. 5 and 6 are circuit diagrams of modifications of the circuit of the device shown in FIG. 2.

Referring to FIG. 1, the device comprises a cylindrical enclosure **2** having sealed into the interior thereof concentric electrodes **3** and **4**, a small permanent magnet **5** between the poles of which is positioned the envelope **2**, and a coil **6** wrapped around the enclosure **2** concentrically with the electrodes. Said electrodes can be of any non-magnetic and conducting material such as copper, aluminum, or carbon. However, it is preferable that they be of a refractory metal such as molybdenum or titanium, or their alloys. The enclosure **2** contains an ionizable medium such as hydrogen, neon, nitrogen, argon, mixture thereof, or an inert compound gas such as freon gas, etc., at a pressure ranging from 10^{-5} to 1 torr. The magnet **5** supplies an axial magnetic field. A power supply **7** is connected across the electrodes **3** and **4**. The coil **6** is connected to said power supply **7** or to another supply. The current **8** flowing through the coil **6** acts as a driving current and controls the main current flow between electrodes **3** and **4** so that it either flows or does not flow in accordance with a novel means of the present invention. This device is essentially a crossed field discharge tube. A perspective sketch of the device is shown in FIG. 2, wherein the reference characters correspond to those in FIG. 1 and the various parts are designated by the same numbers.

For a better understanding of the invention, the static characteristics of the device will be described. FIG. 3 shows variations in sparking voltage and current relative to the axial magnetic field strength. Referring to FIG. 3, full line **110** and dotted line **112** indicate the sparking voltage and a current characteristics respectively of coaxial electrode tubes in an axial magnetic field. It is seen that there is a critical value of magnetic field strength at which the sparking voltage varies abruptly. In FIG. 3, Bc designates the critical magnetic field strength, V*o* are sparking voltages corresponding to magnetic field strengths lower than Bc and Vc are sparking voltages corresponding to magnetic field strengths greater than Bc. The actual magnetic field strength is a combination of the static magnetic field strength B*s* of permanent magnet **5** and the magnetic field strength B*x* of coil **6**. The magnetic field strength B*s* is selected so that its value is lower than the critical magnetic field strength Bc as shown in FIG. 3, while the voltage V*a* applied across electrodes **3** and **4** is adjusted to have a value between V*o* and Vc. When the DC driving current **8** shown in FIG. 2 is not supplied to said coil **6**, i.e. B*x* is zero, the device will be in open circuit condition. If a driving current **8** is supplied to said coil **6**, B*x* appears and the field strength increases. When it becomes higher than Bc, the device will be in the closed circuit condition and a current, Ic in FIG. 3, flows. Therefore the device can be used as a switch by controlling said driving current **8** in said coil **6**.

The device acts as a switch even when the applied voltage is as high as said voltage V*o*, i.e. maximum operating voltage is V*o*. FIG. 4 shows typical variations in said V*o* in relation to the gas pressure of the ionizable medium.

When designing the device, the following essential facts

should be considered: For the achievement of a sharp cut-off characteristic, the gas pressure P in said enclosure must be lower than $\lambda_0/(r_2-r_1)$, where λ_0 is a mean free path of an electron at 1 torr and r_1 and r_2 are the radius of the inner and outer electrodes, respectively. Bc can be expressed as follows:

$$Bc=(2mVa/e)^{1/2}\frac{2r_2}{r^2_2-r^2_1}$$

(inner electrode as the cathode)

$$Bc=(2mVa/e)^{1/2}\frac{2r_1}{r^2_2-r^2_1}$$

(inner electrode as the anode)

where e and m are the charge and the mass of an electron respectively, and Va is the applied voltage. The field strength of the magnet **5** should be slightly lower than Bc. In order to reduce the size of said magnet, it is preferable that the inner electrode be used as the anode. It is also important, in order to increase the operating life, that the electrode materials be refractory metal such as tantalum or molybdenum. When designing the device, the following factors should also be considered. It is necessary to select a suitable material for the aforesaid ionizable medium. A light gas such as hydrogen is suitable if a short ignition time is desired, and for a short quenching time a polyatomic gas such as gaseous ethylalcohol is suitable. The operable life of the device can be prolonged by employing an outer cylinder which is 10–20% shorter than the inner cylinder. A longer outer cylinder frequently causes damage of the envelope at its corner. In order to make the operating voltage of the device that which is desired, the gas pressure and the type of gas therein should be properly selected, various different gases and gas pressures producing various operating voltages. A mixture of various kinds of gases requires special attention to the Penning effect which tends to lower the operating voltage, as disclosed in "Electrical Breakdown of Gases," Oxford Press 1953, edited by J. M. Meek et al. A chemical compound gas such as freon gas is suited for high voltage operation.

The device is essentially a cold-cathode discharge tube. Therefore, the constitution thereof is essentially simpler than a hot-cathode tube such as a thyratron. Since the device has no electric contacts therein, no contact failures need be expected during operating periods. This results in an increase in the operable life. Furthermore, since the device operates in a magnetic field, the deionization time is remarkably shorted. Therefore, the quenching time of the ionized medium in the novel device can be shorter than that of a tube such as a thyratron wherein a magnetic field is not used.

Typical specifications for the device are as follows: The radii of the inner electrode and outer electrode are 5 mm. and 15 mm., respectively. The inner electrode is connected on an anode. The ionizable medium is nitrogen at a pressure of 2×10^{-2} torr. The magnetic field strength of the permanent magnet is 35 gauss. The radius of the coil is 20 mm. the number of turns is 1000 and the driving current ranges from 20 to 30 ma. The maximum controlled current is 50 A., the operating voltage ranges from 500 v. to 10 kilovolts and the time response is 10^{-5} seconds. The operating characteristics of the device can be chosen within the following range: maximum operating voltage is 10 kilovolts or more; the voltage drop between cylindrical electrodes is several hundred volts or less; maximum controlled current is 10 ka.; and the time response is 10^{-4}–10^{-5} seconds.

The device according to the invention can easily be designed to act as a high speed circuit-breaker. Referring to FIG. 1, the cylindrical electrodes **3** and **4** are connected to a load circuit. When the value Bs of the permanent magnet so as to be is chosen slightly larger than the value Bc, the device closes any circuit in which it is connected. When a load current from such a circuit is supplied as a driving current to the coil **6** in a direction to reduce the static magnetic field of the permanent magnet and B is reduced to a value less than Bc, the device opens the circuit. Thus, the load current supplied as a driving current operates said device to the on or off condition.

With the device according to the present invention, a high voltage puulse can easily be generated. Referring to FIG. 5, reference character **11** designates a high voltage DC power supply the out-put voltage of which determines the peak value of a pulse voltage. A stabilizing resistor **12** is connected between one side of supply **11** and the device **13** of the present invention, which in turn is driven by an AC current supply **14**. A small DC voltage supply **15** is connected between device **13** and out-put terminals **16** and controls the level of an out-put pulse. The high voltage pulse is generated by following procedure; high voltage $Va(Va<Vo)$ is applied across the cylindrical electrodes of the device **13** and an AC current is supplied to the coil. During the period of half a cycle of the AC current, the value Bs increases to a value higher than an the value Bc, and accordingly, the device closes the circuit which causes the generation of a high voltage pulse across the out-put terminals **16**.

With the device according to the invention, a DC current controlled device can easily be made. Referring to FIG. 6, a DC power supply **21**, load **22**, and electrodes **23** and coil **24** of the device **27** according to the present invention are connected in series. The DC load current **25** is supplied to the coil **24** in a direction which is the reverse of that of FIG. 2. Therefore, the actual magnetic field strength B decreases with increasing load current. At the usual operating conditions, the magnetic field strength B is selected so as to have a value slightly larger than Bc, and as a result the device **27** closes the circuit. When the load current exceeds a predetermined value B is reduced to a value less than Bc, and the device **27** opens the circuit. By this means, the device **27** can control the load current. An auxiliary circuit **26** is useful for initiating the discharge between electrodes **23**.

It is thought that the invention and its advantages will be understood from the foregoing description and it is apparent that various changes may be made in the form, construction and arrangement of the parts without departing from the spirit and scope of the invention or sacrificing its material advantages, the forms hereinbefore described and illustrated in the drawings being merely preferred embodiments thereof.

We claim:

1. An electric switch of the coaxial cylinder type comprising a gas tight envelope, a pair of cylindrical electrodes enclosed in said gas tight envelope and consisting of an outer cylindrical electrode and an inner cylindrical electrode surrounded at least partially by said outer cylindrical electrode, one of said pair of cylindrical electrodes being a cold cathode and another of said pair of cylindrical electrodes being an anode, an ionizable medium filling said envelope and being at a low pressure less than λ_0/r_2-r_1 torr, where λ_0 is the mean free path of an electron at 1 torr and r_1 and r_2 are the radius of said inner and outer electrode, respectively, magnet means adjacent the outside of said envelope and consisting of a permanent magnet and a coil superposing a magnetic field between said electrodes in a direction transverse to the direction in which said electrodes are spaced, whereby said electric switch closes an electrical circuit across the space between said electrodes when said superposed magnetic field is more than the electron cut-off field Bc and opens said electrical circuit across the space between said electrodes when said superposed magnetic field is less than said electron cut-off field Bc.

2. An electric switch as claimed in claim 1 wherein the strength of the magnetic field of said permanent magnet is less than the electron cut-off field Bc and said coil superposes a magnetic field in a same direction as that of said permanent magnet to close the electric circuit.

3. An electric switch as claimed in claim 1 wherein the strength of the magnetic field of said permanent magnet is more than the electron cut-off field Bc, and said coil superposes a magnetic field in a reverse direction to that of said permanent magnet to open the electric circuit.

References Cited

UNITED STATES PATENTS

1,733,679	10/1929	Toulon	315—348 X
2,039,102	4/1936	McArthur	315—267
2,615,139	10/1952	Coleman	313—158 X
2,892,145	6/1959	Garshelis	313—153 X
3,215,893	11/1965	Boucher et al.	313—161 X

JAMES W. LAWRENCE, *Primary Examiner.*

R. JUDD, *Assistant Examiner.*