July 26, 1966 A. C. KOLB ETAL 3,263,112

MAGNETIC BLOWOUT SWITCH

Filed July 8, 1963

FIG. 1

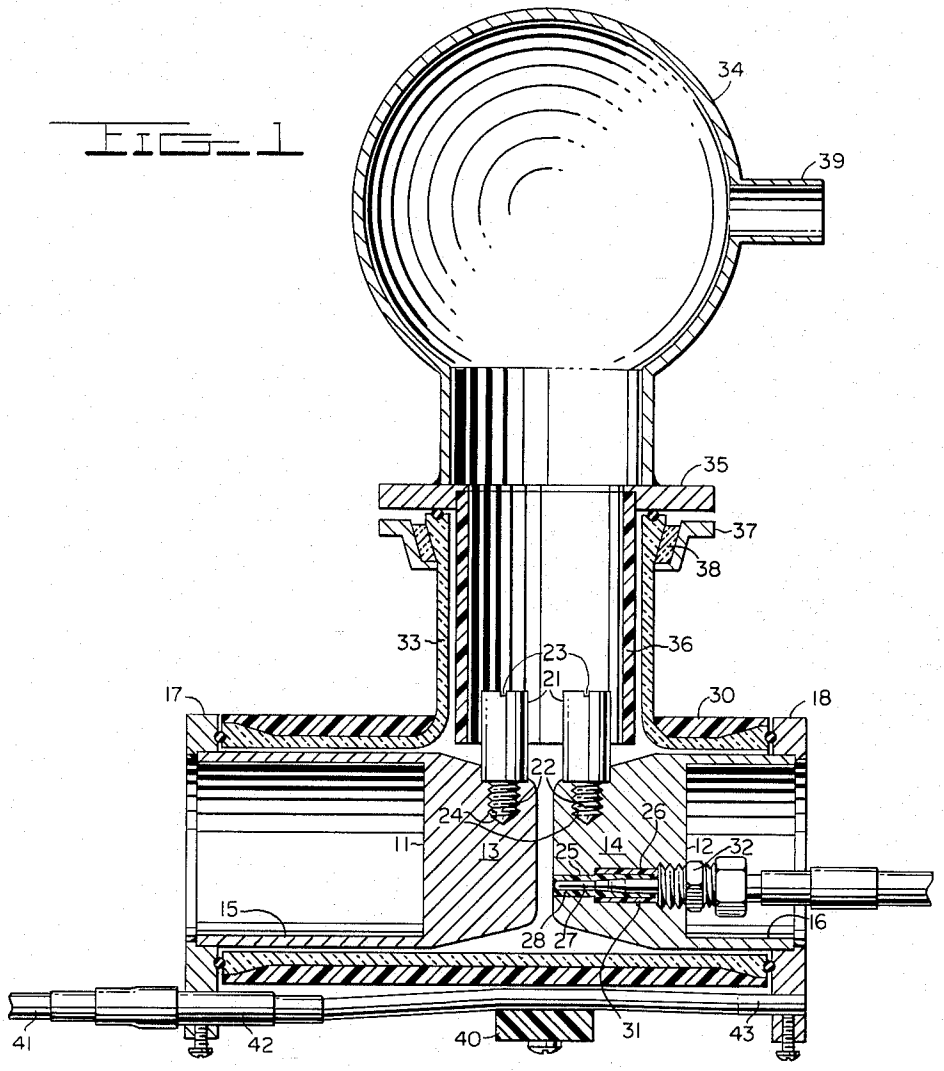
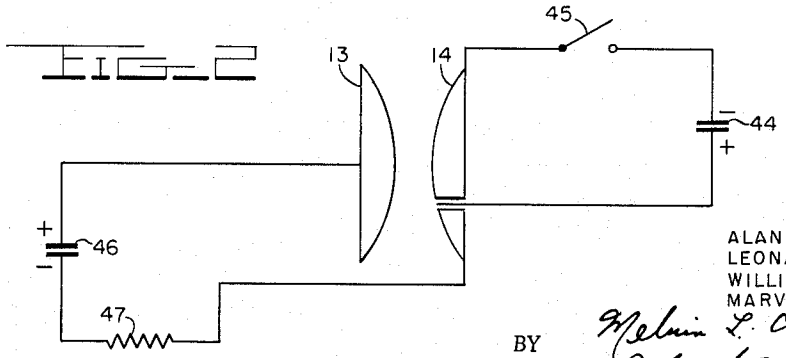


FIG. 2



INVENTORS
ALAN C. KOLB
LEONARD J. MELHART
WILLIAM H. LUPTON
MARVIN P. YOUNG
BY Melvin L. Crane AGENT
Richard A. Reed ATTORNEY

United States Patent Office

3,263,112

Patented July 26, 1966

1

3,263,112

MAGNETIC BLOWOUT SWITCH

Alan C. Kolb, Landover, and William H. Lupton and Leonard J. Melhart, Oxon Hill, Md., and Marvin P. Young, Alexandria, Va., assignors to the United States of America as represented by the Secretary of the Navy

Filed July 8, 1963, Ser. No. 293,566
7 Claims. (Cl. 313—198)

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 a high current, low pressure, low inductance asymmetric switch operable over a wide range of voltages with long life time.

The present invention is an improvement over application Serial No. 213,556 filed July 30, 1962, providing a longer life, high peak current switch operable with times of several hundred microseconds. The operation of this improved switch follows somewhat the principles of operation as set forth in the above identified application.

It is therefore an object of the present invention to provide a simple, long lasting, relatively inexpensive spark gap switch.

Another object is to provide a switch which is operable for currents of about 100,000 amperes with times of several hundred microseconds.

Still another object is to provide a switch capable of switching at least ten kilojoules per discharge in a circuit in which the switch has a major portion of the circuit resistance.

Yet another object is to provide a switch which is operable for low current as well as very high current with very low inductance.

Another object is to provide switching with jitter of less than .1 μsec. with a range of a few hundred volts to tens of kilovolts.

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

FIG. 1 is a cross sectional view of the switch illustrating the relative parts and the arrangement thereof;

FIG. 2 is a diagram of a simple circuit with which the switch may be used.

The spark gap switch of the present invention is made with elongated symmetrical electrodes positioned in end-to-end spaced relationship in longitudinal axial alignment within a "T tube" housing. Electrical energy is supplied to the switching electrodes by coaxial cables or other low inductance conductors, in which one such conductor connects with an end of one electrode and the other such conductor is connected to an end of the other electrode. For illustrative purposes the electrodes are shown connected to coaxial cables. The inner conductor of the coaxial cables or one such conductor parallels the electrodes and the spacing between the electrodes. When a circuit is completed through the cables and across the electrode, a current flows through the completed circuit and a magnetic field is produced about the return current conductor that parallels the electrodes and crosses the spark gap between the electrodes. The magnetic field produced about the return conductor forces the spark

2

and ionized gases produced in the gap between the electrodes away from the electrodes. In order to initiate the firing across the spark gap switch electrodes, an off-axis trigger electrode is added to one of the main electrodes which in discharging a current ionizes the air in the gap causing a discharge across the main electrodes. The discharge produces hot, ionized gases in the vicinity of the gap between the electrodes which carries the current. To prevent wear on the electrode surfaces and to protect the trigger electrode, a tungsten rail is added to each of the electrodes near the gap between the electrodes in parallelism with each other and perpendicular to the longitudinal axis of the electrodes. The tungsten rails can be replaced when worn rather than necessitating replacement of the electrodes which would be required if the tungsten rails were not used.

Now referring to the drawing, there is shown by illustration a suitable switch made in accordance to the present invention and a representative simple circuit for operation of the switch. As shown, the switch comprises electrodes **11** and **12** made from elongated round metal stock of copper, brass, nickel tungsten-copper alloy or any other suitable metal depending on the current flow and the number of firings to be made. The electrodes are symmetrically formed with rounded ends **13, 14.** The rounded ends extend into thin wall cylindrical ends **15** and **16** that connect with circular electrical connectors **17** and **18** that are secured around the ends thereof by welding, brazing or any other suitable method.

Each of the electrodes are provided with solid cylindrical tungsten rails **21** which are provided with screw threads **22** at one end and a slot **23** at the other for securing the rails to the solid adjacent ends of the electrodes in suitable threaded holes **24.** The tungsten rails are secured such that they are perpendicular to the longitudinal axis of the electrodes and parallel to each other. The discharge travels along the rails and reduces the rate of electrode errosion. One electrode is provided with a trigger electrode which is used to trigger the spark gap switch by breaking down the air between the electrodes. An off center aperture is drilled through the electrode below the center line opposite from the threaded holes within which the tungsten rails are secured. The aperture has a portion **25** near the end face of lesser diameter than a portion **26** that extends toward the cylindrical end **16.** A metal rod-like electrical conductor **27** is held in place and surrounded by an aluminum oxide insulator **28** which extends to the end face of the electrode. An appropriate insulator such as an aluminum oxide insulator has a shoulder thereon which seats against the wall formed between the smaller and larger diameter portions of the aperture which receives the trigger electrode. An epoxy resin **31** is formed about the aluminum oxide insulator **28** and fills up the aperture in the electrode to provide a vacuum tight seal between the electrode and the trigger electrode. A coaxial cable is connected to the electrode by any suitable connector **32** which connects the center wire of the coaxial cable to the metal conductor **27** and the outer conductor of the coaxial cable to the electrode **14** through the nut arrangement of the connector **32.** The connector forms no part of the invention; therefore it is not described element by element since any suitable connector can be used.

Heretofore asymmetric spark gap switches have been

used successfully in the open and under certain conditions in an evacuated chamber or one that has a gas therein at a particular pressure. These switches have not been satisfactory for various reasons. The present spark gap switch overcomes these drawbacks through several improvements.

The spark gap switch electrodes **13** and **14** are assembled in opposing ends of a Pyrex T housing **33** and secured therein by use of the electrical connectors **17** and **18** connected thereto. The portion of the T housing within which the electrodes are assembled is potted in epoxy resin **30** to add mechanical strength to the Pyrex housing to help withstand the shock from high energy discharges. The electrical connectors **17** and **18** are attached to the epoxy housing **30** by suitable means. A chamber **34** adapted to be evacuated through tube **39** is secured to a flat plate **35** which has an opening therethrough of a diameter equal to the diameter of the neck portion of the housing by any vacuum tight method and a cylindrical Pyrex or aluminum oxide liner **36** of slightly less diameter than the inner diameter of the neck end of the Pyrex T housing is secured to the flat plate such that when the chamber is secured to the housing, the liner will extend into the neck end of the T to which the chamber is connected such that the free end of the liner is spaced a short distance from the electrodes and beyond a portion of the parallel tungsten rails between the neck portion of the housing and the rails. A metal ring **37** with sloping wall surfaces matching that of the neck end of the T is slid down over the neck end of the T housing and is used to connect the chamber to the T housing. A gasket or spacer **38** is placed between the metal ring and the neck of the Pyrex T to secure the flat plate and the chamber to the neck portion of the housing.

A plurality of coaxial cables **41** are used to complete the current path of the switch. The outer conductor **42** is connected to one electrode and the inner conductor **43** is connected with the other electrode with the inner conductor paralleling the longitudinal axis of the electrodes and across the gap between the electrodes. A phenolic holder **40** is used to clamp the inner conductor of the coaxial cables to prevent the magnetic fields from forcing them out of position.

In assembling the spark gap switch, the electrode with the trigger electrode is prepared with the protected conductor **27** therein ready for securing a coaxial conductor thereto. The Pyrex T housing is prepared by potting the linear ends of the T in an epoxy resin. The liner for the neck of the T is secured to the chamber. The securing ring and gasket **38** for connecting the chamber to the housing neck are put in place. The electrodes are inserted into the housing with the tungsten rail threaded holes facing toward the neck of the housing and with the trigger electrode on the side away from the neck. The tungsten rails are secured in the threaded holes in the electrodes and the electrodes are then secured in place by connecting the electrical connectors to the resin covering. The cables are connected to the main electrodes and to the trigger electrode. The sleeve on the chamber is inserted into the neck of the T housing and the chamber is then secured to the housing by use of the metal ring and suitable screws or bolts. Each end of the T housing is provided with O rings to prevent leakage between the housing and the attached electrodes and chamber.

The use of the Pyrex T housing makes it possible to reduce the switch inductance, the trigger electrode assembly is less complex and the creepage path for voltage breakdown is preserved. The epoxy resin potted around the housing adds mechanical strength to the Pyrex housing to help withstand the shock from high energy discharge and lowers the cost by simplifying the mountings of the electrodes and cable terminals.

The liner inserted into the neck is replaceable and protects the housing at the point of greatest wear thereby extending the lift time of the housing by about ten times. The tungsten rails extend into the area surrounded by the Pyrex liner such that when a discharge is made a magnetic field about the coaxial cable parallel to the electrodes forces the arc and ionized gas along the tungsten rails therefore the tungsten rails absorb most all of the wear and damage due to a discharge whereas normally the electrodes absorb this wear. The use of the cable as the back strap to produce the magnetic field reduces the number of parts and produces a much simpler device. Also the trigger electrode is moved off the center of the electrode which protects the trigger electrode by being further away from the arc produced between the tungsten rails. This also provides better firing reliability.

The previously used chambers made of organic materials released so much gas during high energy discharges that the system could not be evacuated fast enough with reasonable size evacuating equipment. Also, the organic matter contaminated the evacuating pump. The Pyrex glass T does not give off any gases and also aids in preventing voltage breakdown between the electrodes which occurs along the surface of the housing made of other materials. Other ceramic chambers could also be used as well as Pyrex. Pyrex T's come as normal stock equipment in different sizes therefor different sizes are readily available for different energy switches. Since these T's are readily available, production costs are lower than possible if each switch housing were to be made separately. Switches such as described above have increased lifetime and provides good efficient switching.

FIG. 2 illustrates a simple circuit diagram illustrating the electrical connections of the spark gap switch and the trigger electrodes to operative power sources. As shown, the trigger electrode is connected with the positive side of power source **44** and the negative side of the power source is connected with electrode **14** of the spark gap switch that includes the trigger electrode. The electrical circuit is controlled by any suitable switch **45** including switches based on designs described herein and completed between the end of the trigger electrode and the electrode **14** through the air in the vicinity of the electrodes. The positive side of power source **46** is connected with the other electrode **13** of the spark gap switch and the negative side of the power source **46** is connected with the electrode **14** of the spark gap switch through a load represented by a circuit element **47**. Although these polarities are preferred the switch can also be operated with the polarities reversed from the manner in which described.

In operation, each of the capacitor power sources **44** and **46** are charged and prepared for operation. The switch that controls the trigger electrode circuit is closed causing a discharge between the end of the trigger electrode and the electrode of the spark gap switch within which the trigger electrode is assembled. This discharge ionizes the gases between the spark gap electrodes which permits a discharge between the main electrodes of the spark gap switch. The time of firing of the main circuit depends on the initiating spark and the polarity and spacing between the electrodes of the spark gap switch. A discharge across the gap between the spark gap switch electrodes permits a current flow through the load. At the time of discharge between the main electrodes, a magnetic field is set up about the conductor backing the switch gap, this magnetic field forces the spark discharge away from the backing conductor. The spark will be forced away from the ends of the electrodes along the surface of the tungsten rails. Thus the most severe erosion or burning effects that occur will take place away from the immediate adjacent ends of the electrodes. The magnetic field set up about the backing conductor not only forces the spark away from the ends of the electrodes but forces any contaminants away from the electrodes such that the area between the electrodes is not contaminated. Therefore for best operation the switch functions better if used with the chamber facing downwardly so that any contaminants will fall into the chamber and not back onto the electrodes. Therefore the switch should be used when

rotated 180 degrees from the showing in the drawing. The shape of the electrode ends permit an asymmetrical discharge between the spark gap switch electrodes and the tungsten rails absorb any burning or harmful effects normally occurring on the electrodes. Thus the electrodes are not effected by the discharge between the electrodes.

Switch electrodes such as described and set forth above can be made in any desired diameter depending on the current to be used. As an example, cylindrical electrodes of 3.18 cm. diameter of brass stock with a trigger electrode of about 2.5 mm. diameter of copper stock have been fired several thousand times with a peak current of 80,000–100,000 amperes lasting several hundred microseconds with very little deleterious effect on the electrodes.

With a chamber such as shown in FIG. 1 the switch may be operated from a low vacuum pressure to high pressure gases depending on the use and evacuated through connector **39** by any suitable evacuating equipment.

It will be obvious to make different electrical connections with the electrodes, however, it is important for long life operation of any spark gap switch to make the switch with one conductor backing the gap to provide a magnetic field that blows any contaminants and the spark away from the ends of the electrodes. The electrical connections in the illustrated switch are for illustrative purposes only and this is by no means the only manner by which electrical connections can be made with the spark gap switch.

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. A low inductance, spark gap switch adapted to be connected with the conductor lines of an electrical power supply which comprises:

(a) a T-shaped housing,

(b) said housing including a neck portion adjoining axially aligned end portions,

(c) a protective coating on the outer surface of said axially aligned end portions,

(d) first and second elongated, symmetrical, cylindrical, axially aligned electrodes secured in spaced relationship within said axially aligned end portions relative to the axis of said neck portion of said housing,

(e) an aperture in said first electrode off the axis thereof and positioned on the side thereof opposite from said neck portion of said housing,

(f) a trigger electrode,

(g) said trigger electrode passing through said aperture in said first electrode with the inner end thereof even with the end of said first electrode adjacent to said second electrode,

(h) a pair of elongated, cylindrical rails, and

(i) said rails extending into the area confined by said neck portion of said housing in parallelism and secured to adjacent ends of said first and second electrodes in spaced relationship perpendicular to the longitudinal axis of said electrodes with said rail on said first electrode being secured on a side thereof directly opposite from said trigger electrode.

2. A low pressure, low inductance switch adapted to be connected with the conductor lines of an electrical power supply which comprises:

(a) a T-shaped housing,

(b) said housing including a neck portion adjoining axially aligned end portions,

(c) a protective coating on the outer surface of said axially aligned end portions,

(d) first and second elongated symmetrical, cylindrical, axially aligned electrodes secured in spaced relationship within said axially aligned end portions of said

housing relative to the axis of said neck portion of said housing,

(e) an aperture in said first electrode off the axis thereof and positioned on the side thereof opposite from said neck portion of said housing,

(f) a trigger electrode,

(g) said trigger electrode being secured within said aperture in said first electrode with the inner end thereof secured even with the end of said first electrode adjacent to said second electrode,

(h) a pair of elongated, cylindrical rails,

(i) said rails extending into the area confined by said neck portion of said housing in parallelism and secured to adjacent ends of said first and second electrodes in spaced relationship perpendicular to the longitudinal axis of said electrodes with said rail on said first electrode being secured on a side thereof directly opposite from said trigger electrode,

(j) a chamber secured to said neck portion of said housing, and

(k) a liner secured to said chamber extending into said neck portion between said rails and the housing wall surface of said neck portion.

3. A low pressure, low inductance switch as claimed in claim **2** wherein an electrical conductive coaxial cable having inner and outer conductors is connected to said first and second electrodes with said outer conductor connected to said second electrode and said inner conductor extending parallel with the longitudinal axis of said electrodes in close relationship thereto and connected to said first electrode.

4. A low pressure, low inductance switch as claimed in claim **3** wherein a coaxial cable is connected with one conductor connected to said trigger electrode and the other conductor of said coaxial cable connected to said first electrode.

5. A low pressure, low inductance switch adapted to be connected with the conductor lines of an electrical power supply which comprises:

(a) a T-shaped housing,

(b) said housing including a neck portion adjoining axially aligned end portions,

(c) a protective coating on the outer surface of said axially aligned end portions of said T-shaped housing,

(d) first and second elongated, symmetrical, cylindrical, axially aligned electrodes secured in spaced relationship within said axially aligned end portions relative to the axis of said neck portion of said housing,

(e) an aperture in said first electrode off the axis thereof and positioned on the side thereof opposite from said neck portion of said housing,

(f) a trigger electrode,

(g) said trigger electrode being secured within said aperture in said first electrode with the inner end thereof secured even with the end of said first electrode adjacent to said second electrode,

(h) a pair of elongated, cylindrical rails,

(i) said rails extending into the area confined by said neck portion of said housing in parallelism and secured to adjacent ends of said first and second electrodes in spaced relationship perpendicular to the longitudinal axis of said electrodes with said rail on said first electrode being secured on a side thereof directly opposite from said trigger electrode,

(j) a chamber secured to said neck portion of said housing,

(k) a liner secured to said chamber extending into said neck portion between said rails and the housing wall surface of said neck portion,

(l) an electrical conductive coaxial cable having inner and outer conductors connected with said outer conductor connected with said second electrode and said inner conductor extending parallel with the longitudinal axis of said electrodes proximate thereto and connected to said first electrode, and

(m) a coaxial cable connected with said trigger electrode and said first electrode.

6. A low pressure, low inductance switch as claimed in claim 5 wherein said protective coating on the outer surface of said T-shaped housing is of epoxy resin.

7. A low pressure, low inductance, switch as claimed in claim 6 wherein said liner is made of aluminum oxide.

References Cited by the Examiner

UNITED STATES PATENTS

2,293,529	8/1942	Bedford	316—64 X
2,431,226	11/1947	Berky et al.	313—239 X
2,506,687	5/1950	Scherrer	313—237
2,565,945	8/1951	Bockman	313—325 X
2,909,698	10/1959	Garner	313—237
2,936,390	5/1960	Melhart	313—325 X
2,940,011	6/1960	Kolb	313—161 X
2,946,923	7/1960	Fitch	315—241 X
3,042,828	7/1962	Josephson	313—237 X
3,128,255	4/1964	McGary et al.	117—161 X

DAVID J. GALVIN, *Primary Examiner.*

GEORGE N. WESTBY, *Examiner.*

R. JUDD, *Assistant Examiner.*