Sept. 26, 1961 C. A. BURRUS 3,002,069

ELECTRIC SWITCH

Filed Dec. 29, 1959

FIG. 1

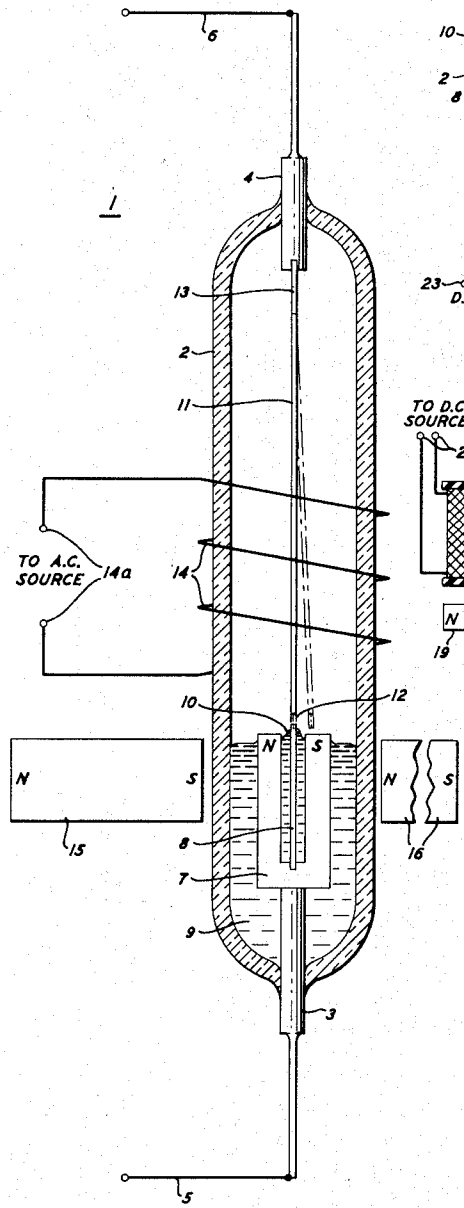


FIG. 3

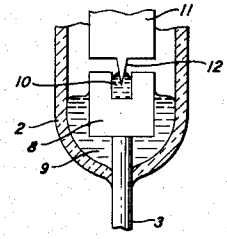


FIG. 3A

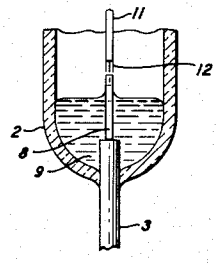


FIG. 4

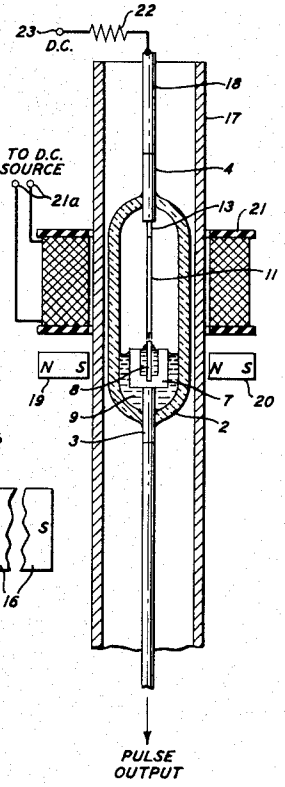
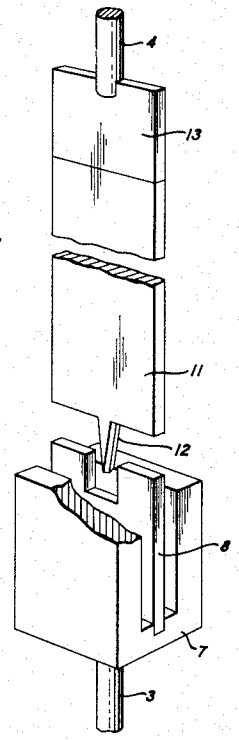


FIG. 2



INVENTOR
C. A. BURRUS

BY
Stoddard

ATTORNEY

United States Patent Office 3,002,069 Patented Sept. 26, 1961

3,002,069

ELECTRIC SWITCH

Charles A. Burrus, Red Bank, N.J., assignor to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

Filed Dec. 29, 1959, Ser. No. 862,525
1 Claim. (Cl. 200—112)

This invention relates to electric switches and, more particularly, to electric switches of the mercury contact type.

An object of this invention is to provide an improved mercury contact for use in an electric switch.

Another object of the invention is to provide an improved mercury contact switch capable of extremely rapid cyclical operation.

Still another object of the invention is to provide an improved mercury contact switch which is particularly adapted to form the center conductor of an electric coaxial line.

A further object of the invention is to provide an improved mercury contact switch for use in producing a train of pulses each of very short duration and having extremely fast rise time.

These and other objects of the invention are accomplished by mounting a bifurcated member at the bottom of an essentially cylindrical glass envelope or housing of an electric switch. The glass envelope is closed at each end and its lower portion contains a pool of mercury surrounding the bifurcated member which is of such dimensions that the upper ends of its forks project slightly above the surface of the pool of mercury. Due to the effects of surface tension and capillary action, a thin section of mercury is formed between the forks in an elevated position with respect to the surface of the pool as is more fully described hereinafter. The elevated section of mercury functions as one of the two contacts of this switch.

The other contact of the switch is constituted by the tip of a movable armature which is suspended from the top of the glass envelope in such a manner that its lower end or tip extends into the elevated section of mercury but deos not quite reach the surface of the pool. This armature is adapted to be electromagnetically controlled or operated so that its lower end will swing transversely through the elevated mercury section. The movement of the armature through the mercury section is facilitated by providing the end of the armature with a knife-like edge.

During the operation of this switch, the armature cyclically swings back and forth rapidly between the forks of the bifurcated member and into and out of the elevated mercury section. When the armature is in the section of mercury, an electric connection is made. This connection is broken when the armature swings out of the mercury section. Thus, the operating time consumed in making and breaking a connection is only the few millimicroseconds required for the knife-edge of the armature to slice through the thin elevated section of mercury. It is to be noted that two connections are made during each cycle of the armature. When this switch is used in a pulse generator, the repetition rate of the resulting pulses will be twice the driving frequency.

These and other features of the invention are more fully discussed in connection with the following detailed description of the drawing in which:

FIG. 1 is a sectional view of an illustrative switch in which the features of this invention are embodied;

FIG. 2 is an enlarged perspective view showing the armature suspended above the bifurcated member which is represented as being interposed between two magnetic members;

FIGS. 3 and 3A are sectional views of the lower portion of the switch showing a modified construction thereof; and

FIG. 4 is a schematic diagram partly in section illustrating the manner in which the switch of FIG. 1 is incorporated in a discharge line type of pulse generator.

While the invention is not limited to a switch of any given size or proportions, it should be noted that this switch is particularly useful when it is connected in series with the center conductor of an electric coaxial line. For this purpose, the switch may be made with extremely small dimensions, and it should therefore be understood that the figures shown in the drawing are greatly enlarged in order to facilitate a clearer comprehension of the construction of the switch.

The illustrative embodiment of the invention shown in FIG. 1 is represented as an electric switch **1** having an essentially cylindrical glass envelope or housing **2** which is closed at each end. In this embodiment of the invention, the envelope is about one and three-eighths inches long and has an outside diameter of approximately three-sixteenths of an inch. Two terminals **3** and **4** are mounted in opposite ends of the envelope **2** with a portion of each extending inside the envelope **2** and another portion projecting outwardly therefrom. These terminals **3** and **4** are electrically conductive and are made of any appropriate material, such as an alloy of nickel and iron, having substantially the same coefficient of expansion as the glass envelope **2** so that the joints between the terminals **3** and **4** and the envelope **2** will form a gas-tight seal. Prior to the sealing operation, a suitable gas, such as hydrogen is introduced inside the envelope **2** under high pressure for the purpose of improving the operating characteristics of the switch **1** and for prolonging its useful life. Two electric conductors **5** and **6** are connected respectively to the terminals **3** and **4** in any suitable manner. These conductors **5** and **6** constitute part of an electric circuit that is controlled by the switch **1**.

The portion of the lower terminal **3** that extends inside the envelope **2** supports a U-shaped envelope **7** of magnetic material which is not wettable by mercury. This member **7** is securely fastened to the terminal **3** in any convenient manner. The interior bottom portion of the member **7** serves as a base upon which is fixedly mounted, in any suitable manner, a bifurcated nonmagnetic member **8**, having a thickness of between three thousandths of an inch and one hundredth of an inch. These members **7** and **8** are almost completely submerged in a pool of mercury **9** contained in the bottom of the envelope **2** which serves as a reservoir.

As is indicated in the drawing, a small section **10** of mercury is raised or elevated above the surface of the pool **9** and is supported in the space between the forks of the member **8** due to the effects of surface tension and capillary action. In order to facilitate wetting of the forks of the member **8** by the mercury, the member **8** is made of copper coated with platinum. In this embodiment of the invention, the inside spacing between the forks of the member **8** is about two hundredths of an inch and the top of the elevated mercury section **10** is about four hundredths of an inch above the surface of the mercury pool **9**. As was stated above, this minute elevated mercury section **10** constitutes one of the two contacts of the switch **1**.

The portion of the upper terminal **4** that projects inside the envelope **2** has attached thereto a movable armature **11** of the vibrating or resonant reed type. This armature **11** is made of any suitable magnetic material and, in this form of the invention, is of such dimensions that it is designed to have a resonant frequency of about one kilocycle. The length of this armature **11** is sufficient for the maximum downward extent of travel of its lower end to reach only to an intermediate point between the

top of the elevated mercury section 10 and the surface of the pool of mercury 9. In this embodiment of the invention, the bottom of the tip 12 extends about two hundredths of an inch into the elevated mercury section 10. For the purpose of facilitating the movement of the armature 11 through the mercury section 10, its lower end is formed in a sharp, tapered point or tip 12 and is provided with a knife-like edge so that it can easily and quickly slice through the mercury section 10 with a minimum of resistance. Since the tip 12 forms the other contact of the switch 1, it is coated with an appropriate material, such as platinum, so that it can be easily wetted by the mercury. The armature 11 is joined to the terminal 4 by a section 13 of spring steel welded thereto so as to increase its flexibility and thereby to increase the rapidity of its vibration or movement.

Movement of the reed or armature 11 is effected by means of a driving coil or winding 14 which is connected to a source 14a of alternating electric current having the same frequency as the resonant frequency of the reed 11, which, in this example, is one kilocycle. By thus using an alternating current supply 14a having the same frequency as the resonant frequency of the reed 11, it is possible for the reed 11 to obtain its maximum amplitude of swing while it is vibrating thereby insuring that it will swing completely away from the mercury. It should be noted that the upright portions of the U-shaped member 7 are not so tall as to interfere with the movement of the reed 11. The driving or operating coil 14 is wound around the middle portion of the envelope 2. Although only a few turns of the winding 14 have been shown in the drawing for the purpose of simplicity, it is to be understood that the coil 14 may actually consist of a solenoid having a large number of turns.

The driving action of the coil 14 is assisted by two permanent magnets 15 and 16 which are located outside the glass envelope 2 in close proximity to the pool 9 of mercury. The magnets 15 and 16 are disposed on opposite sides of the envelope 2 with their ends facing the broad sides of the U-shaped member 7, which, as was stated above, is made of magnetic material. The magnets 15 and 16 are further arranged so that their ends which are adjacent to the envelope 2 are of opposite polarity. Due to the magnetic force induced by the magnets 15 and 16, the two upright portions of the U-shaped member 7 function as pole-pieces.

At this point, it is appropriate to state that the function of the U-shaped member 7, which is of magnetic material, is to enhance the fields of the external magnets 15 and 16. If desired, the member 7 can be omitted provided stronger magnets are substituted for the magnets 15 and 16. Such a modification of the interior construction of the switch 1 is illustrated in FIGS. 3 and 3A. In this form of the switch 1, it is convenient to have the bifurcated member 8 directly supported on, or attached to, the upper end of the lower terminal 3.

From the above description of the structure of the switch 1, it can be understood that the electric path between the leads 5 and 6 is closed through the switch 1 when the armature tip 12 is in the elevated mercury section 10 and is opened when the tip 12 swings out of the mercury section 10. It is to be noted that the platinum coating on the tip 12 is readily wettable by the mercury thereby assuring that good electric contacts are made. When the tip 12 moves away, the mercury section 10 becomes broken or disrupted but it quickly resumes its elevated position. As the armature 11 swings back, its tip 12 again enters the mercury section 10 and briefly re-establishes the electric connection. This connection is of very short duration because the tip 12 quickly slices through the extremely thin mercury section 10. Since the amount of mercury contained in the elevated section 10 is so minute and is so thin, it presents negligible resistance to the passage of the tip 12 and, consequently, has substantially no damping effect on the movement of the reed 11. Thus, the electric connection is interrupted twice during each cycle of the reed 11 with a complete absence of contact chatter. Accordingly, when the reed 11 is vibrated at the rate of 1,000 cycles per second, the circuit will be interrupted 2,000 times in one second.

As was stated above, this switch 1 is particularly useful when it is connected in series with the center conductor of a coaxial line since it can then function as a pulse generator for producing pulses with extremely fast rise time and of very short duration. The manner in which the switch 1 is installed for this purpose is illustrated in FIG. 4 which shows a discharge line type of pulse generator comprising an open-circuited coaxial line constituted by an outer cylindrical conductor 17 of non-magnetic material surrounding an inner coaxial conductor 18. Instead of connecting the switch terminals 3 and 4 to conductors 5 and 6, the terminals 3 and 4 are now connected in series with the inner coaxial conductor 18. This can be done in any convenient manner, such as by welding. The function performed by the magnets 15 and 16, shown in FIG. 1, is accomplished by similar magnets 19 and 20 which are attached to the outer coaxial conductor 17.

In this embodiment of the invention, the driving coil 14 of FIG. 1 is replaced by a driving solenoid 21 formed around the outside of the outer conductor 17 and having its axis along the reed 11. This solenoid 21 is connected to a source 21a of alternating current similar to the alternating current source 14a described above. It is to be noted that the upper portion of the inner coaxial conductor 18, which is connected to the upper switch terminal 4, is also connected through a resistor 22 to a source 23 of direct current voltage which applies a charge to this open-ended coaxial line 17—18. During operation, the charged coaxial line 17—18 is cyclically discharged at the rate of 200 times in one second by the switch. This produces a train of very short pulses each having an unusually fast rise time and each having a length equal to or less than the time required for the reed tip 12 to slice through the elevated mercury section 10.

The switch 1 is particularly adapted for forming part of a coaxial line as it has a substantially uniform cross-section along its length. This construction minimizes reflections that might otherwise be caused by an impedance mismatch along the line and is thereby conducive to the production of pulses having the desired sharp shape. The pulse shape is further improved due to the fact that the structure of the switch 1 as was explained above is such that it produces no contact chatter during operation of the switch 1.

What is claimed is:

An electric switch comprising an envelope member containing at one end a pool of mercury, a terminal having a portion extending outside said envelope and another portion projecting inside said envelope and submerged in said pool, a U-shaped member of magnetic material positioned in said pool and attached to the terminal portion therein, said U-shaped member having two arms and an interior bottom portion, means for elevating a section of said mercury above the surface of said pool with the bottom of said section contiguous with the surface of said pool, said means comprising a bifurcated member of non-magnetic material having forked portions, said bifurcated member being mounted on the interior bottom portion of said U-shaped member and between the arms thereof, the forked portions of said bifurcated member being so proportioned as to project above the tops of the arms of said U-shaped member and also to protrude above the surface of said pool while their bottom portions remain submerged in said pool of mercury, magnetic means external to said envelope for oppositely polarizing the arms of said U-shaped member, an armature of magnetic material mounted above said pool for move-

ment of its tip transversely between the forks of said bifurcated member, and electromagnetic means external to said envelope for cyclically changing the polarity of said armature tip, said armature having a length sufficient for the maximum downward extent of travel of its tip to reach only to an intermediate point between the

surface of said pool and the top of said elevated section of mercury.

References Cited in the file of this patent

UNITED STATES PATENTS

2,792,329 George ---------- June 25, 1957