July 22, 1958 A. H. GOTTFRIED ET AL 2,844,687

ELECTROMECHANICAL SWITCHING ELEMENT

Filed Aug. 3, 1956

FIG. 1

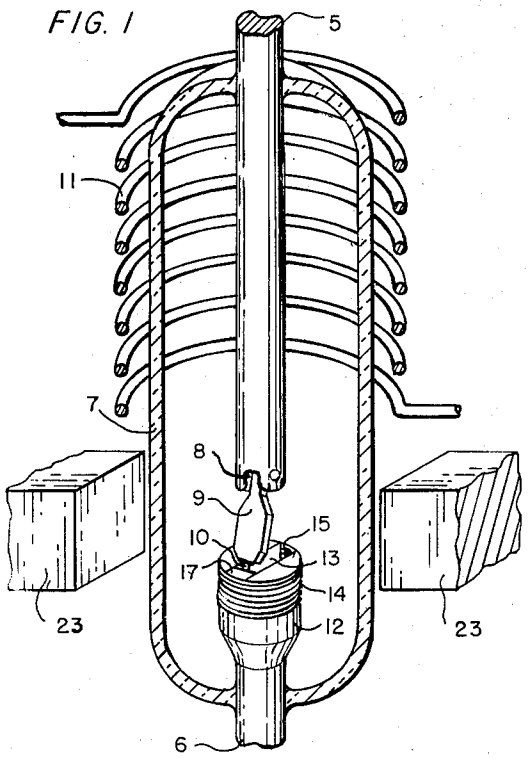


FIG. 2

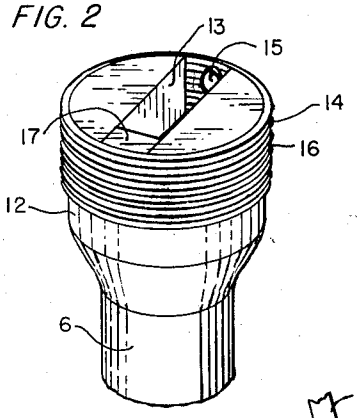


FIG. 3

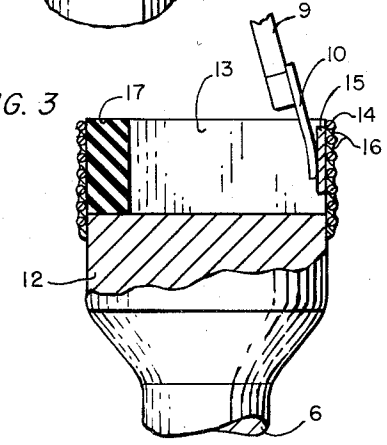
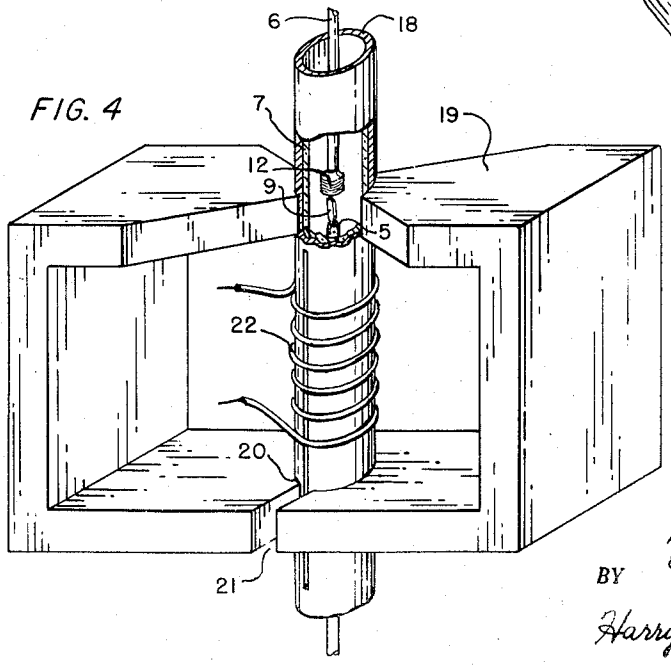


FIG. 4



INVENTORS,
ARTHUR H. GOTTFRIED
& KURT IKRATH.

BY

Harry M. Saragovitz
ATTORNEY

United States Patent Office 2,844,687 Patented July 22, 1958

2,844,687

ELECTROMECHANICAL SWITCHING ELEMENT

Arthur H. Gottfried, Rumson, and Kurt Ikrath, Long Branch, N. J., assignors to the United States of America as represented by the Secretary of the Army

Application August 3, 1956, Serial No. 602,086

5 Claims. (Cl. 200—112)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment of any royalty thereon.

This invention relates to an electric switching device capable of rapidly opening and closing an electric circuit in response to a changing electromagnetic field.

The mechanical and electrical features of the invention make it highly useful for pulsing high frequency energy at high repetition rates. The repetition rate is established by the frequency of a varying impressed magnetic field.

Switches of the cantilever or vibrating reed type have been used in switching service similar to that to which the invention is adapted but have proved to be unsatisfactory in many respects. The practice of the invention provides a switch which eliminates the unsatisfactory features of conventional switch types. A more detailed account of the invention with respect to conventional devices will be set forth hereinafter.

A highly satisfactory embodiment of the invention is its encapsulated form which will be described herein. It is to be understood, however, that the invention embraces other forms suitable for diverse applications. The capsule within which the switch is received may be made small, and consequently the assembled switch may be received in a limited space. For example, a practical form of the switch permits its use in connection with a high frequency radio transmission coaxial line. When so used, the standing wave ratio values of the line remain substantially normal. In a preferred form of the invention the moving element of the switch is contained within an envelope of insulating material such as glass having a nonoxidizing atmosphere. A pair of electrodes of electrically conductive material preferably at least one of which is of magnetic material such as soft iron are sealed into the glass envelope in an end-to-end relation, the outer ends of the electrodes extending through the glass. These electrodes constitute the conductors for the controlled energy passing through the device.

The contacting element of the switch is of special construction, consisting of a small vane or armature of magnetic material pivoted to the end of the magnetic electrode and is movable into contact with the other electrode. The armature is caused to swing on its pivot from closed to open position under the influence of a changing magnetic field applied outside of the envelope.

To promote high efficiency and constant contact impedance, the point of contact is fed with mercury by means of a system for feeding mercury from a reservoir to the contact point which will be described in detail hereinafter. This special contact wetting system provides the benefits of low resistance contacts without the undesirable features associated with the mercury bath type of switch wherein a contact member is forced through a pool of mercury.

The contactor in applicants' device may be so designed that the repetition rate of its cycle is extremely high and still provide true synchronous response to its driving energy. It will also be shown hereinafter how the device of the invention is adaptable to be incorporated in a coaxial transmission line for controlling high frequency energy.

It is a primary object of the invention to provide an electrical switching means which is highly versatile in its applications.

A further object of the invention is to provide an electromechanical switch capable of efficient operation at fast repetition rates.

A further object of the invention is to provide an electromechanical switch in which the contact surfaces are automatically renewed.

A further object of the invention is to provide a switch whose size and construction permit its placement within a coaxial transmission line without seriously affecting the favorable or normal standing wave ratio for the line in which it is incorporated.

A further object of the invention is to provide a switch of the type described in which a constant low impedance is maintained in the closed circuit portion of its cycle.

Other objects and features of the invention will more fully appear from the following description and will be particularly pointed out in the claims.

To present a better understanding of the invention, particular embodiments thereof will be described and illustrated in the accompanying drawings wherein Fig. 1 is an enlarged perspective view, partially in cross section, of a preferred embodiment of the invention; Fig. 2 is a detailed view in perspective illustrating the construction of one of the electrodes of the switch; Fig. 3 is a cross sectional view of the electrodes shown in Fig. 2; Fig. 4 is a perspective view illustrating a specific application of the switch.

As shown in Fig. 1 of the drawings, a pair of wires or rods **5** and **6** are sealed into the ends of a glass envelope **7**. Desirably the rods are rigidly held in aligned relation as a result of the sealing operation. The electrodes are constructed of magnetic material and one of them, for instance the electrode **5**, is provided with a slot **8** within which is received the tang of a pivoted armature member **9** of magnetic material such as soft iron. The armature may be relatively short in length and correspondingly light in weight. Such an armature has low inertia which permits it to be driven at high vibratory speeds and moreover its response to impressed magnetic fields is extremely fast. Its pivot offers small frictional drag which constitutes an additional factor to enhance the speed and versatility of the device.

Electrical contact between the armature **9** and the fixed contact electrode **6** may be made in any suitable manner. A desirable construction, however, is to provide a platinum wire **10** which is secured to and extends outwardly from the lower end of the armature **9**. The wire **10** may be secured to the armature in any suitable manner such as by welding.

The driving energy for the switch is provided by a coil **11** surrounding the envelope **7** and energized by a modulated signal. Desirably, also, the magnetic system of the device includes a fixed magnet **23** within the field of which the armature **9** is immersed. A more detailed description of the function of the device involving the magnetic fields will appear hereinafter.

The coacting fixed electrode **6** of the switch desirably has a slightly enlarged end portion **12** within which an open-ended slot **13** is formed extending diametrically across the electrode in the direction of travel of the armature **9**. The electrode **6** is so positioned that the wire contact No. 10 moves in the slot but does not contact its walls. A closely spaced coil of metallic wire **14** is wound upon the enlarged end of the electrode **6** bridging across the open ends of the slot. The wire **14** de-

sirably is made of platinum and may be held in place upon the electrode by spot welding thereto at spaced intervals or the end of the electrode may be provided with a shallow spiral groove cut therein to receive the wire. The platinum contact plate **15** is welded to the inner surface at the point where the wires bridge across one end of the slot **13**.

A quantity of mercury **16** is placed upon the coil **14** and is held between the turns thereof by adhesion. The mercury thus received by the wire **14** constitutes a reservoir acting constantly to feed mercury to the plate **15** which becomes wetted by a thin coating thereof. The contact wire **10** and the armature **9** are also provided with a coating of mercury. The surface of the wire **10** and the armature **9** may be pre-wetted with mercury or may receive their supply of mercury by contact with the plate **15** during operation of the switch. Thus the contact points of the switch are constantly supplied with mercury and also the pivot for the armature **9** receives a supply of mercury which acts to lubricate the pivot and also to maintain a low and substantially constant impedance at the pivot. It will be noted in the drawing that the presence of the mercury is indicated upon the wire **14** in Fig. 3 of the drawing. Its presence in thinly coated form is assumed to exist upon the contact points of the switch and the armature **9** although not specifically shown in the drawing, such showing being difficult of achievement.

The end of the slot **13** opposite the plate **15** has secured therein a block of non-wetting insulating material **17**. The block **17** serves as a stop for the armature **9** to limit its movement in the open circuit portion of its cycle and since the block is made of insulation it acts to prevent electrical contact with the electrode **6** at all times except when the armature is in the closed circuit portion of its cycle.

In operation, the armature **9** causes the contacting wire **10** to move in the slot **13** in response to a varying magnetic field induced by the coil **11**. The movement of the armature causes its contactor **10** to engage the plate **15**, thus to close the circuit. When the polarity of the field changes the armature **9** swings the contact away from the plate to open the circuit.

The armature, its pivot and its driving means may be designed to achieve optimum performance much more favorable than conventional devices of a similar nature. The size and weight of the armature may be varied to respond accurately to a wide range of repetition rates. Also, its extent of travel may vary freely. This flexible design feature accounts to a large extent for the versatility of the invention. Moreover, the electrical efficiency of the switch is high since its contacts are self-cleaning and function in a manner to overcome splashing of the mercury.

The scope of the invention embraces many applications and permits varied means of driving the contacting armature 9. As shown in Fig. 4 of the drawings, the capsule type switch illustrated in Fig. 1 may be inserted directly into a coaxial transmission line where the electrodes **5** and **6** and the armature **9** become the inner conductor and a metallic tube **18** enclosing the envelope **7** becomes the outer conductor of the coaxial line. The tube **18** may be of a size to be suitably coupled to the coaxial line itself in which the energy to be controlled is flowing. In conjunction with the switch, a magnetic circuit is established in any suitable manner to impress a constant field upon the armature **9**.

A desirable arrangement for accomplishing this result is shown in Fig. 4 wherein a permanent magnet **19** applies its field to the switch. The magnet **19** desirably is of the horseshoe type having its pole tips directed at diametrically opposite points upon the tube **18** adjacent the armature **9**. A convenient unitary structure is attained by providing an aperture **20** in the magnet within which the tube **18** is received. In this manner, the magnet functions to support the tube. Also a transverse slot **21** is cut in the magnet to aid in reducing eddy currents. A slot also may be made in the tube **18** for the same purpose.

A driving coil **22** surrounds the tube **18** and is designed to have the required ampere turns to drive the switch. The operating characteristics of a switch designed according to the invention permit the coil **22** to function with a low value of input energy. The coil **22** is supplied with alternating current having a frequency proportional to the desired repetition rate of the switch. In operation, therefore, the armature will vibrate at the required rate to make and break the circuit through the switch contacts.

The overall characteristics of the invention render it adaptable to many uses. The extremely fast make and break ability of the switch enable it to function at high operating speeds required for short duration pulse formation and fast switching. In a cantilever type switch the shape of the driving current wave is critical. Harmonics of the driving current can drive the cantilever switch at spurious modes and repetition rates, whereas in the pivoted armature design of the invention the shape of the driving current is not critical. Moreover, a cantilever type switch inherently has a limiting factor controlling its high repetition rate range, namely, the natural mechanical spring constant of its reed. In the device of the invention it can be shown that high repetition rates can be achieved without encountering limiting factors. Reed fatigue which occurs in the cantilever type switch does not exist in the pivoted armature design of the invention.

The operation of the pivoted armature of the invention is not hampered by resonant factors. The chief factor which could be a limiting condition in its operation relates to the pivot bearing for the armature **9**. The damping effect of the pivot can be mathematically expressed by the following.

$$\frac{2\alpha}{D/\phi_{\max.}}$$

where α is the pivot friction damping; D is the design parameter including the magnet and the armature dimensions; and $\phi_{\max.}$ is the angle of motion necessary to make and break contact. It has been found that the quantity indicated by the above expression can readily be held below unity, which is the critical maximum. If this maximum is greater than unity at certain frequencies the driving current may become very high. If the quantity is held below unity the possible frequency of repetition rate is limited only by the strength of the driving current. Thus it is entirely practical to avoid critical damping at the pivot.

What is claimed is:

1. An electromagnetic switch comprising a gas-tight envelope having an inert atmosphere therein, first and second electrically connectable rigid electrodes at least one of which is of magnetic material within said envelope in spaced relation and having external electrical connections for insertion in an electric circuit, a rigid armature of magnetic material pivoted to said first electrode and extending toward the second electrode, a fine mesh metallic fabrication secured to said second electrode a supply of mercury on said fabrication, said fabrication having interstices charged with mercury, a contact secured to said fabrication in position to be engaged by said armature to make electrical contact therewith, said contact being fed by capillary action with a film of mercury from the said supply, a magnetic system including an electromagnet positioned outside said envelope acting to immerse said armature in its field and a source of rapidly modulated current connected to said electromagnet.

2. An electromechanical switch comprising a gas-tight envelope having an inert atmosphere, first and second rigid connectable electrodes at least one of which is of magnetic material within said envelope and having external electrical connections for insertion in an electric circuit, said electrodes being located in spaced relation, a rigid

armature of magnetic material pivoted to said first electrode at its inner end and extending toward said second electrode, said second electrode having a recess opening to the outer surface thereof at least at the end thereof adjacent said first electrode and at one side thereof, a coil of wire wound upon said second electrode having at least some of the turns thereof passing across the side opening of said recess, a contact plate secured in electrical contact with the coil at said side opening, said second electrode being positioned to receive the said pivoted armature within its recess and to cause said armature to engage said plate when it moves into closed circuit position, a supply of mercury received upon and between the turns of said coil whereby said fixed contact is fed by capillary action with a thin coating of mercury, a magnetic system including an electromagnet positioned outside said envelope acting to immerse said armature and at least a portion of said electrodes in its field and a source of rapidly modulated current connected to said electromagnet.

3. An electromechanical switch according to claim 2 and wherein a block of insulation is received in the said recess at its end remote from said contact plate thereby to prevent said armature from making electrical contact with said second electrode when in its open circuit position.

4. An electromechanical switch according to claim 2 and wherein the said armature is provided with a small flexible extension acting to make and break electrical contact with said contact plate.

5. An electromechanical switch comprising a gas-tight envelope, first and second spaced rigid electrodes at least one of which is of magnetic material sealed in said envelope and having external connections for insertion in an electrical circuit, a rigid magnetic armature pivoted to and electrically connected to said first electrode and extending towards said second electrode, said armature positioned to swing into and out of closed circuit position with said second electrode, a permanent magnet having its poles placed in position to apply a high flux density to said armature and so arranged that the flux of the magnetic circuit will traverse said armature and at least a portion of said electrodes, a hollow tubular conductor surrounding said envelope and embraced by the poles of said permanent magnet, said hollow conductor constituting the outer conductor of a coaxial transmission line and the said electrodes and armature constituting the inner conductor of said coaxial line and an electromagnetic coil surrounding said hollow conductor whereby the flow of energy in the coaxial system may be controlled by a modulated signal fed to said electromagnetic coil.

References Cited in the file of this patent

UNITED STATES PATENTS

2,264,124	Schreiner	Nov. 25, 1941
2,303,474	Kalb	Dec. 1, 1942
2,445,406	Pollard	July 20, 1948
2,491,986	Larson	Dec. 20, 1949
2,508,508	Garvin	May 23, 1950
2,540,479	Gehrand	Feb. 6, 1951
2,609,464	Brown et al.	Sept. 2, 1952