

March 8, 1966

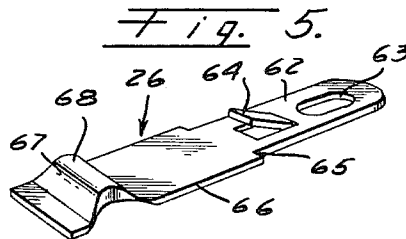
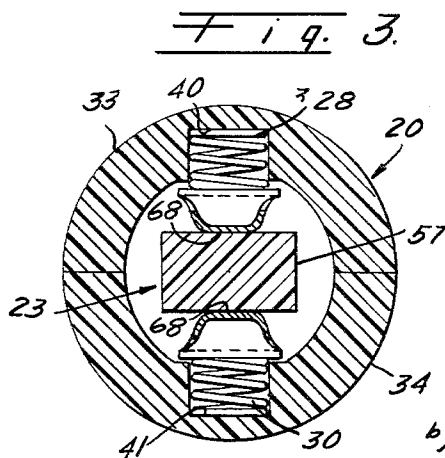
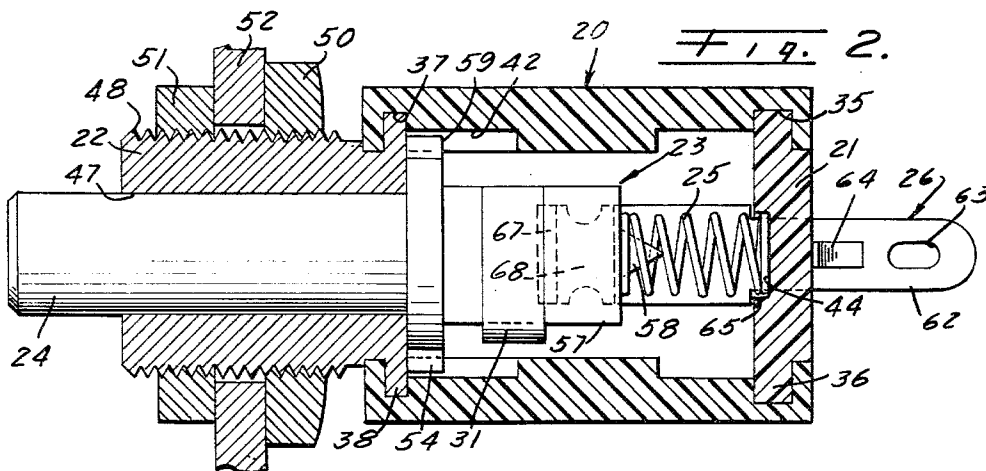
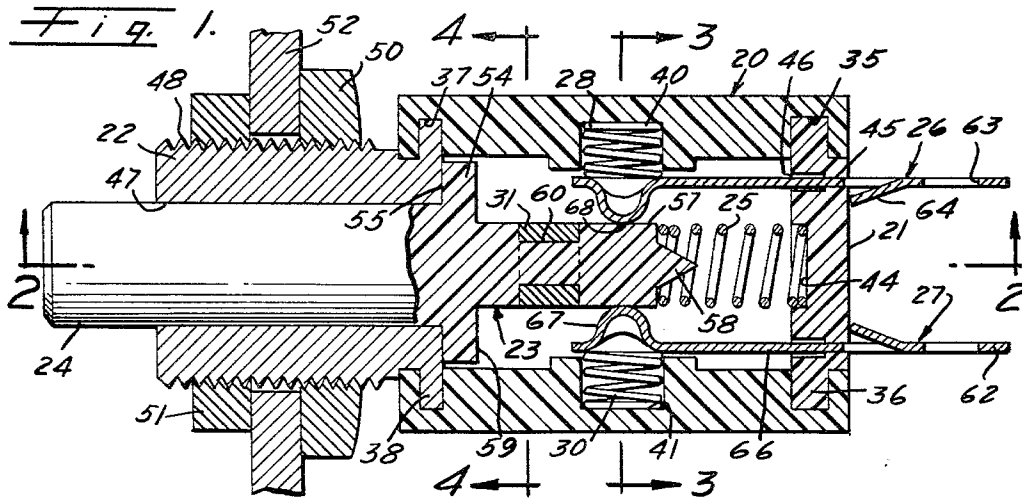
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3,239,637

ELECTROMECHANICAL DEVICES

Filed Dec. 3, 1962

3 Sheets-Sheet 1



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Fig. 6.

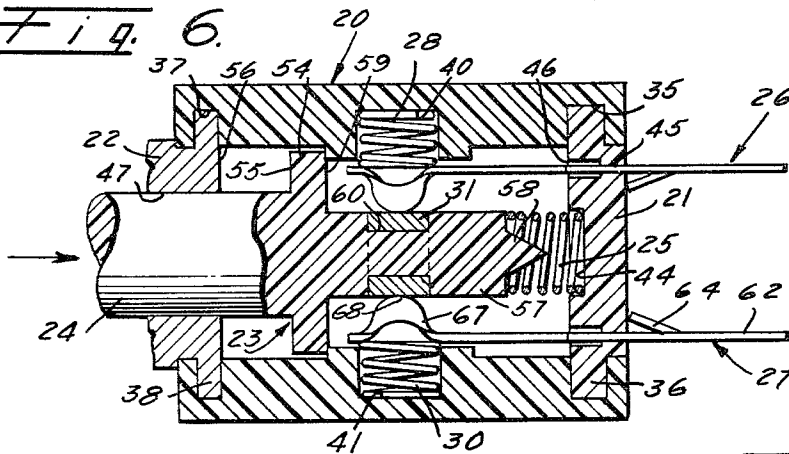


Fig. 4.

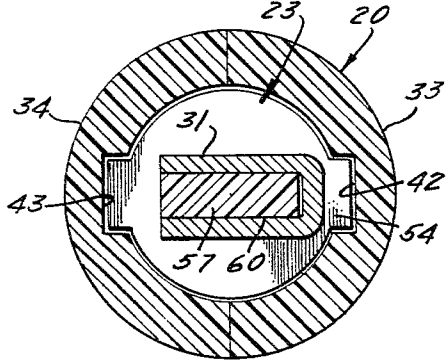


Fig. 7.

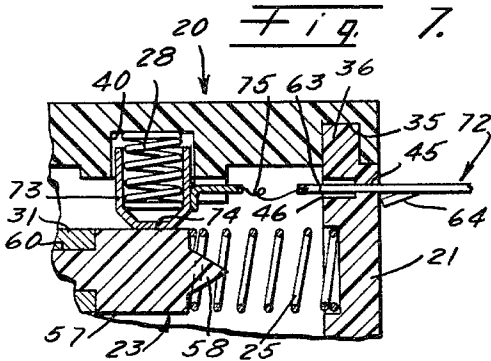


Fig. 9.

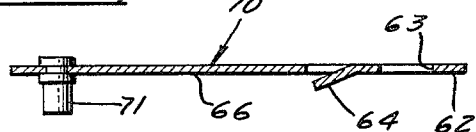
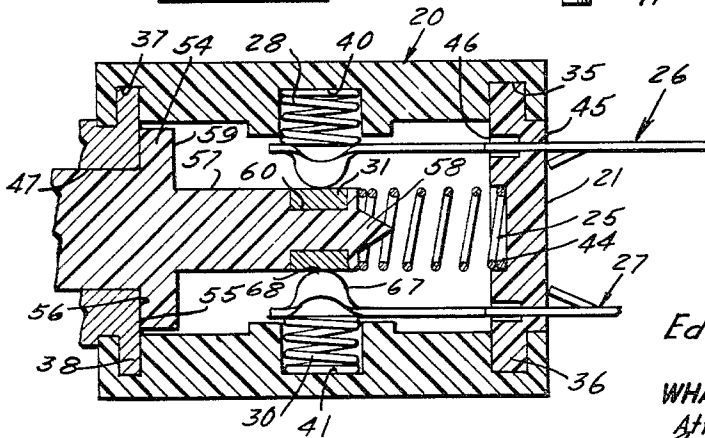


Fig. 8.



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Fig. 10.

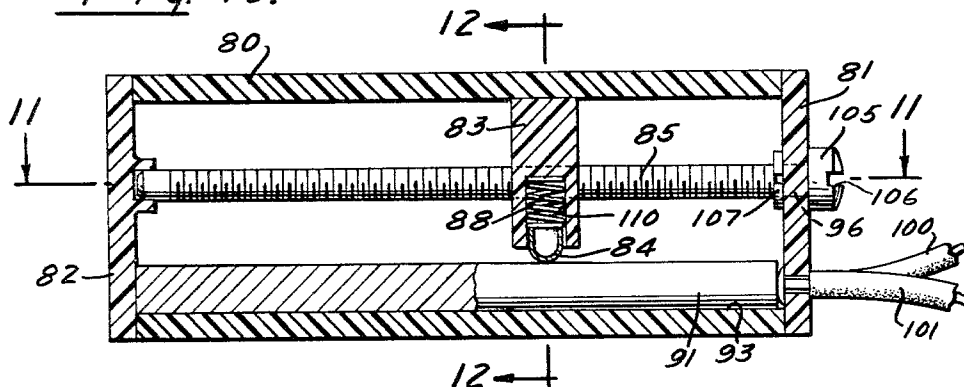


Fig. 11.

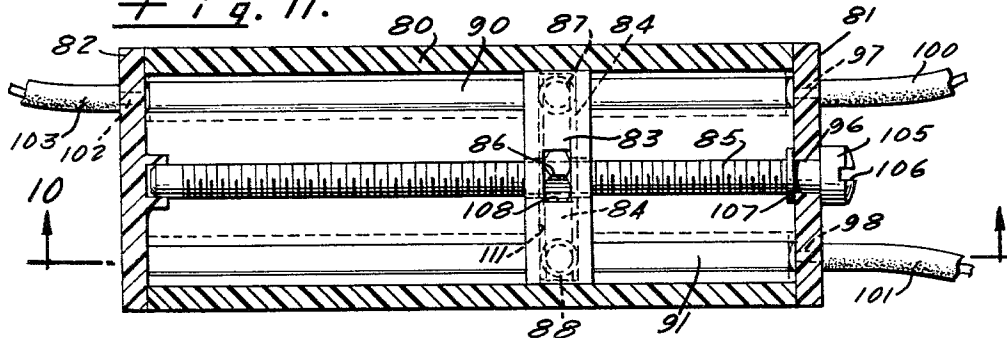


Fig. 12.

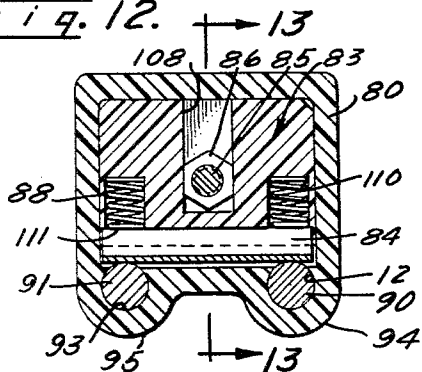


Fig. 13.

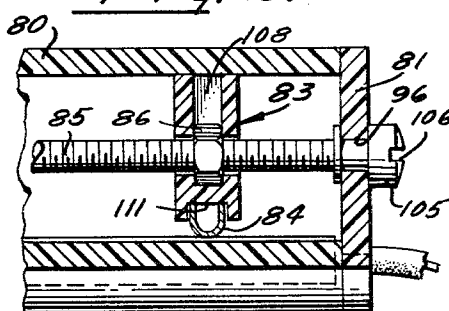
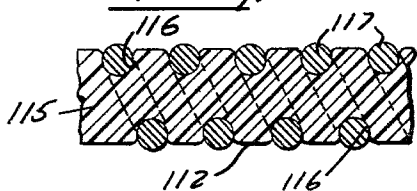


Fig. 14.



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ELECTROMECHANICAL DEVICES

Edwin F. Pierce, Pasadena, Calif., assignor to E. and P. Engineering Research and Development Corporation, Reno, Nev., a corporation of Nevada
Filed Dec. 3, 1962, Ser. No. 241,676
10 Claims. (Cl. 200-164)

This invention relates generally to electromechanical devices, and particularly relates to various types of switches including relays or potentiometers utilizing sliding contact between two contact elements for making or breaking an electric circuit or for changing the resistance thereof.

Electric switches may be classified depending upon the manner in which making or breaking of an electric circuit is effected. One type of switch may be called a button-type switch. Here, the two electric contact elements consist of leaf springs provided with contact buttons which are forced into contact, for example, by a cam, a rocker arm or a solenoid. In another type of electric switch, a wiper arm forming one of the contact elements slides over a conductive fixed contact. Thus, in a sliding-contact switch, the wiper arm generally slides from an insulating portion over a conductive portion. The same principle may be utilized in potentiometers where the wiper arm slides over a resistive element.

In a button-type switch, the contact pressure between the two contact elements must be carefully balanced. If the contact pressure is too high, the contacts bounce before they actually make contact. As a result, two or three separate signals are created before the electric circuit is finally connected. Furthermore, the bouncing may cause an electric arc to form between the contact elements which may give rise to high peak voltages lasting for milliseconds or microseconds. Additionally, arcing causes pitting, oxidation and erosion of the contacts which in turn varies the electric contact resistance of the switch erratically during its life. This is detrimental for most applications. On the other hand, if the contact pressure between the two button conductors is too low, dirt which accumulates between the contacts increases the contact resistance. In order to avoid the troubles encountered due to corrosion or oxidation of the contact elements, rare materials have been used for the contact buttons which, of course, increases the price of the switch.

Furthermore, various anti-arc devices have been proposed to minimize arcs between the contact elements. In spite of these precautions which increase the price of a button-type switch, the life of such a switch is relatively limited and generally does not exceed 100,000 cycles of operation.

The other class of switches may be designated a sliding-contact or wiper-type switch. Generally, such switches are operated with a relatively low contact pressure. If a high contact pressure is used, the wear of the metal contacts is considerably increased. As a result, worn off metal particles may deposit over the insulating portion over which the wiper arm slides. Eventually, the insulating portion becomes covered with metal so that the electric circuit can no longer be broken. This phenomenon is usually referred to as tracking. With a high contact pressure this problem becomes acute within a few hundred cycles of operation.

On the other hand, a wiper-type switch operated with relatively low contact pressures causes erratic make and break of the electric circuit. Furthermore, the contact resistance of the switch is again variable over its life and subject to abrupt changes. This contact resistance may be due to oxidation of the contacts or to corrosion by the atmosphere which may contain sulphur. With a low contact pressure, it is not possible to break through such

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an oxide film or other film of chemical compounds or impurities which may form on the switch contacts. Again, the life of a conventional wiper switch is limited to 50,000 to 100,000 operations.

Various switches are known which use lubricants to lubricate rotary or movable elements of the switch. It has also been proposed to utilize oil to quench an arch which may form between the switch contacts during high voltage operation. However, in the past, switch contacts by themselves have not been lubricated.

It is accordingly an object of the present invention to provide an improved electromechanical device such as a switch or potentiometer which has a long life.

Another object of the present invention is to provide a switch where the sliding contact elements are lubricated and are pressed against each other with a pressure sufficient to break through the lubricating film on the contact elements.

It is a further object of the present invention to provide an improved switch of the sliding contact type which will give an improved signal not subject to bouncing of the contacts or erratic operation.

Still another object of the invention is to provide a switch of the type referred to which has a contact resistance that is low and remains constant throughout the useful life of the switch.

Yet another object of the present invention is to provide an electromechanical device such as a switch or potentiometer having sliding contacts and characterized by an insulating lubricant on the contacting surfaces for imbedding particles worn off the contacting surfaces.

Still a further object of the present invention is to provide a switch of the sliding contact type where the switch contacts are protected from oxidation, corrosion or chemical attack which might vary the contact resistance in an erratic manner.

Yet another object of the present invention is to provide an improved switch which will withstand vibration and at least 100g, where g is the acceleration of gravity of the earth.

An electromechanical device, in accordance with the present invention, is characterized by sliding contacts while a lubricant is disposed between the sliding contact elements. This lubricant must be electrically insulating and has a high dielectric constant. The purpose of the lubricant is to imbed or encapsulate in the lubricant particles worn off the contact elements, such as metal particles, during sliding motion thereof. In this manner, the worn off metal particles are electrically insulated from each other and cannot cause short circuits of the switch. The contact pressure between the contact elements is preferably at least large enough to break through the lubricating film disposed over the contact elements.

This concept of the present invention is applicable to any type of switch or relay utilizing sliding contacts. It may also be utilized in a potentiometer where a wiper arm slides over a resistive element to increase or decrease the electric resistance in an electric circuit.

Preferably, a relatively high contact pressure between the two contact elements is provided. A high contact pressure will cause sufficient wear of the contact elements so that they always remain clean. Any corrosion film or oxide film which may form on the metal contacts will be rubbed off due to the high contact pressure. Furthermore, the lubricant will protect the contact surfaces from the effects of oxidation, corrosion or other chemical action.

The principles of the invention have been illustrated by way of example as applied to a push button switch and to a linear potentiometer. The linear potentiometer disclosed and illustrated herein, is claimed in a copending application of Edwin F. Pierce entitled "Linear Potentiometers." This copending application is filed concur-

rently herewith, Serial No. 241,674. However, it will be apparent that the principles of the present invention are applicable to many other electromechanical devices such as rotary potentiometers and many other types of switches or relays utilizing sliding contact between their contact elements.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, wherein like elements are designated by the same reference characters, and in which:

FIG. 1 is a sectional view of a normally open push button switch embodying the present invention;

FIG. 2 is a sectional view taken on line 2—2 of FIG. 1;

FIG. 3 is a cross sectional view of the push button switch of FIG. 1 taken on line 3—3 of FIG. 1;

FIG. 4 is a cross sectional view taken on line 4—4 of FIG. 1;

FIG. 5 is a view in perspective of one of the two contact and terminal elements of the push button switch of FIG. 1;

FIG. 6 is a sectional view, parts being broken away, similar to that of FIG. 1 and illustrating the push button switch in its actuated or depressed position;

FIG. 7 is a fragmentary sectional view of a modified push button switch in accordance with the present invention utilizing separate contact elements and terminal elements;

FIG. 8 is a fragmentary sectional view similar to that of FIG. 1 and illustrating a normally closed push button switch in accordance with the present invention;

FIG. 9 is a side elevational view of a modified contact element and terminal embodying the present invention;

FIG. 10 is a sectional view of a linear potentiometer in accordance with the invention;

FIG. 11 is a sectional view taken on line 11—11 of FIG. 10;

FIG. 12 is a cross sectional view taken on line 12—12 of FIG. 10;

FIG. 13 is a fragmentary sectional view taken on line 13—13 of FIG. 12; and

FIG. 14 is a longitudinal sectional view of a modified resistive element for a linear potentiometer in accordance with the invention.

Referring now to the drawings and particularly to FIGS. 1 through 6, there is illustrated the preferred embodiment of the invention which is a normally open push button switch embodying the present invention. Such push button switches, whether normally open or normally closed, find wide application. For example, push button switches are utilized for energizing a light usually provided in the roof of a car upon opening of the car door. Similar switches are utilized in connection with the doors of refrigerators or closets. Hence, the push button switch of the invention may be utilized to energize any electric light, for testing electric or electronic circuits or computers or for operating a relay such as a latching relay. Furthermore, push button switches may be utilized for testing purposes in combination with an indicator lamp. Such a push-to-test switch may be utilized for testing various electronic circuits such as a flip-flop. They find wide use in radar or television broadcast stations and may further be provided for manual control of electronic circuits. If a light-duty switch with low power rating is provided, it may be used to operate a relay which in turn may control large electric power.

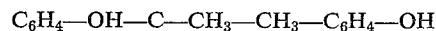
The normally open push button switch illustrated in FIGS. 1 through 6, generally includes a housing 20, an end cap 21, a hollow end fitting 22, an armature 23, which may be made integral with the push button 24, a return

spring 25 for the armature, two contact and terminal elements 26 and 27, two contact springs 28 and 30 and a shorting clip 31 forming the movable contact element.

The housing 20 generally has the form of a hollow cylinder of circular cross section and preferably consists of two identical semi-cylindrical portions 33 and 34 as shown particularly in FIGS. 3 and 4. This construction permits ready assembly of the switch. The housing 20 is provided with an annular recess 35 at one of its ends for mounting therein end cap 21. To this end, the end cap 21 has an annular projection 36 which fits into the recess 35 of the housing 20. The other end of the housing 20 is also provided with a similar annular recess 37. A corresponding annular projection 38 of the end fitting 22 fits into the recess 37. The end fitting 22 may be externally threaded as shown. Each of the two housing portions 33 and 34 is provided with a substantially cylindrical recess 40 and 41 for receiving one of the contact coil springs 28 and 30. These recesses 40 and 41 may be circular in cross section to support and retain the two contact springs.

Furthermore, the housing 20 is provided near its end adjacent the end fitting 22 with two elongated longitudinal recesses 42 and 43 as shown particularly in FIG. 4 for preventing rotation of the armature 23.

The housing 20 may be made from an insulating plastic material having good electrical properties including a high dielectric constant such, for example, as a polycarbonate. A polycarbonate is a polymer derived from biphenol A or 4,4' dihydroxy diphenyl propane. This compound has the chemical formula



Such a polycarbonate is sold in the trade under the name of Lexan by General Electric Company. This plastic material may be readily molded and can be cheaply made in mass production. It is also characterized by great impact strength.

The end cap 21 is provided with a central recess 44 of cylindrical shape facing the interior of the housing for retaining the return spring 25. Preferably, the last coil of the return spring 25 has a press fit with the recess 44. The end cap 21 is further provided with two rectangular openings 45 through which the contact and terminal elements 26 and 27 may extend. The openings 45 may be relieved as at 46 to permit bending of the terminal elements 26 and 27.

The end cap 21 may be made of any insulating material which will withstand high temperatures, that is, of the order of over 300° F., and which has good electrical properties including a high dielectric constant. The material of end cap 21 must withstand the relatively high temperature created when a conductor is soldered to the two terminal elements 26 and 27. For example, the end cap 21 may consist of a black phenolic which is mineral filled. This material has all the required properties.

The two housing portions 33 and 34 may be secured together or joined in any suitable manner. For example, the two housing portions 33 and 34 may be cemented together, they may be heat-sealed or riveted or they may be connected by metal straps or metal bands. Lexan, of which the housing is preferably made, has also good cementing characteristics and stability. Thus, the housing 20 is preferably connected together by applying a solvent to the edges of the two housing portions. Within a few seconds the solvent will dissolve a thin surface layer of the Lexan whereupon the two housing portions may be joined together under pressure and become firmly cemented. It may be mentioned here that Lexan is preferably not used for the end plate 21 because this plastic material will flow at the higher temperatures generated while soldering conductors to the terminal elements.

The end fitting 22 has a cylindrical bore 47 extending therethrough for receiving the actuating button 24. Furthermore, the end fitting 22 may have external threads,

as shown at 48. A hexagonal nut 50 and a knurled ring nut 51 may be threaded on the end fitting 21 for securing the switch, for example, to a panel as indicated at 52. The end fitting 22 may consist of any suitable material. For example, the end fitting may consist of aluminum or aluminum alloy which may then be anodized to resist corrosion.

The armature 23 which is the movable element of the switch may be made integral with the operating button 24 as shown. The armature 23 is formed with two projections 54 of generally rectangular outline which fit into the recesses 42 of the housing 20. These projections 54 are provided with shoulders 55 which are normally pressed by return spring 25 against the annular end portion 56 of the end fitting 22. The armature 23 further includes a dependent body portion 57 of generally rectangular cross section as shown for example in FIG. 3. A conical end portion 58 is provided on the armature 23 for holding and retaining the return spring 25. Accordingly, the return spring 25 is disposed between the conical end portion 58 of the armature 23 and the recess 44 of the end fitting 21. A reduced portion or recess 60 generally of C-shape, as shown particularly in FIG. 4, extends circumferentially about the dependent body portion 57 for receiving the shorting clip 31 which forms the second contact element. The contact clip 31 is press-fitted over the recess 60 of the armature body portion 57.

The armature 23 again may consist of any insulating material having good electrical properties including a high dielectric constant. Preferably, the armature is molded from Lexan or other polycarbonate.

The return spring 25 is preferably a coil spring of some material having good spring properties.

The shorting clip 31 should consist of any suitable metal having good electrical conductive properties. For example, the shorting clip 31 may be made of copper or brass which is nickel-plated to provide a superficially porous (minutely pitted) surface on the clip to assure that the surface is covered with a film of insulating lubricant except where the spring biased contacts (described below) break through the film to conductively engage the clip.

One of the two combined terminal elements and contacts 26 and 27 is shown particularly in FIG. 5. The terminal element includes a reduced end portion 62 having an aperture 63 for soldering or otherwise connecting thereto a conductor. As clearly shown, for example, in FIG. 1, the terminal element 62 protrudes from the end cap 21. There is further provided a punched-out or lanced portion 64 which may have a rectangular shape as illustrated. This lanced portion 64 rests against the end plate 21 as shown particularly in FIG. 1 and thus prevents undesirable movement of the terminal element. A shoulder 65 is formed between the reduced terminal end portion 62 and the enlarged contact portion 66. The shoulder 65 rests against the end cap 21 as clearly shown in FIG. 2. Hence, each of the two combined terminal elements and contacts 26 and 27 is locked in position between the shoulder 65 resting on the end cap 21 and the projecting lanced portion 64.

The actual contact surface is formed by an extruded portion 67 having substantially flat, rectangular or elongated surfaces 68, which contacts the armature 23. The contact springs 28 and 30 respectively bear against the extruded portions 67 of the two terminal elements 26 and 27 to press them against the armature.

The contact and terminal elements 26 and 27 preferably consists of an alloy known as nickel-silver which includes 81% copper and 18% nickel. However, any conducting material which has a flaking action may be used for the contact elements.

FIG. 9 illustrates a modified contact and terminal element 70 which has a separate contact button 71 riveted or otherwise secured to the terminal element. The terminal element 70 may otherwise be the same as that shown, for example, in FIG. 5. If a separate contact button is

used as illustrated in FIG. 9, the contact button may be made of an alloy known as coil silver which consists of 92% silver and 8% copper. Alternatively, the contact button 71 may consist of palladium, platinum, rhodium or gold. These metals have the property that they are resistant to chemical action and hence the contact surface remains clean. They also have a flaking action which helps to maintain a clean contact surface.

The push button switch of the invention as illustrated in FIGS. 1 through 6 may be assembled as follows:

At first, the two terminal and contact elements 26 and 27 are pushed through the end cap 21 with their terminal portions 62. After the shoulder 65 contacts the end cap 21 the lanced portion 64 of each element is pushed out to lock the two terminal elements. Then, the actuating button 24 is inserted into the end fitting 22. Thereupon, the return spring 25 is inserted into the recess 44 in the end cap 21. Furthermore, the two contact springs 28 and 30 are inserted in their respective recesses 40 and 41 in the two housing portions 33 and 34. Then, the two housing portions 33 and 34 are assembled about the annular projection 38 of the end fitting 22 and about the annular projection 36 of the end cap 21.

Finally, the two housing portions are connected together in any of the manners previously outlined, for example, by cementing. The thus assembled switch may then be clamped to a panel 52 by the two nuts 50 and 51. In addition, the lubricating material or dielectric fluid should maintain its characteristics over a normal ambient temperature range which may extend from below room temperature to at least +160° F. The lubricating material should further adhere to the contact surfaces with a very rapid surface flow. As a result, when the sliding contact or brush wipes the surface free, the lubricating material should flow back substantially as fast as the brush or contact moves.

By way of example, the insulating lubricating material which is used in accordance with the present invention may include a major proportion of mineral oil of the type used for high voltage transformers. This mineral or transformer oil withstands high temperatures as well as low temperatures and has a high dielectric constant because it is used for transformers carrying up to 300,000 volts. This mineral oil or transformer oil may be emulsified and may have a base of a tallow grease which will not carbonize out under conditions of wear. A mineral detergent may be added to increase the wetting action or to decrease the surface tension.

An insulating lubricant of this type is sold in the trade under No. 871 Switch Lube by Lubrication Company of America. This insulating lubricant includes at least 93% mineral oil and is of relatively high viscosity. Thus, at 100° F., the viscosity may be 2,600 centistokes per second. This mineral oil has a flash point at 550° F. In other words, when the oil is heated to 550° F., it will flash under the influence of an electric arc. Thus, the lubricant will withstand arcing up to 550° F. It may further be added that No. 871 Switch Lube shows substantially no corrosion.

The metal particles worn off primarily from the elongated contact surfaces 68 are imbedded or encapsulated in the insulating lubricant which is used to lubricate the contact surfaces. Since the lubricating material used in accordance with the present invention has a high dielectric constant, the worn off metal particles are insulated from each other and cannot cause undesirable short circuits over the insulating armature portion 57. In other words, the worn off metal particles are imbedded or encapsulated within a film that is thick enough so that individual metal particles are insulated from each other. Thus, even if these metal particles are arranged in a chain, they should be insulated from each other so that they will not conduct current when the switch is in the open position. Additionally, the film of lubricant should be of such a nature to prevent the worn off metal par-

ticles from being imbedded in the insulating material such as the dependent body portion 57. As a result, these worn off metal particles are unable to form a conductive path when the switch is in the open position.

On the other hand, due to the high dielectric constant of the lubricating material, it is necessary that the contact pressure be large enough to break through the film of lubricating material. Thus, the contact pressure should be high enough to break through the lubricating film.

The contact pressure between the elongated surface portions 68 and the shorting clip 31 should be high enough to break through the insulating film disposed about the cooperating contact elements. The contact pressure required for this will vary with the particular materials used for the cooperating contact surfaces and with the properties of the insulating and lubricating film. However, it has been found that if the contact pressure is too low, the contact resistance increases and erratic operation of the circuit takes place. At this time, it is believed that this is due to the insulating and lubricating film building up under the spring-urged contact surface 68 and lifting it from the shorting clip 31 and thereafter permitting it to make a metal-to-metal contact again. On the other hand, a high contact pressure is sometimes desirable because such a high contact pressure will scrape off or wear off any film of oxidation or other impurities or dirt particles which may form on the contacting metals.

Accordingly, at the present time it is preferred to utilize a contact pressure of at least 100 pounds per square inch and preferably of 800 pounds per square inch or higher. As the contact areas wear, the contact areas increase and hence, the pressure in pounds per square inch decreases from the original 800 pounds per square inch and may reduce to about 400 pounds per square inch at the end of the useful life of the switch. However, it should be noted that the switch of the present invention can be operated at lower pressures, that is, at pressures below 100 pounds per square inch.

The contact area between the extruded elongated portion 68 and the shorting clip 31 should be large enough to carry the maximum current for which the switch is designed. The size of this area can be readily determined from conventional conductivity tables and depends on the particular materials used.

Regardless of the particular construction of the switch, arcing always remains a problem. In the first place, arcing causes erratic operation of the switch. In other words, the contact resistance is subject to certain changes. Furthermore, arcing causes pitting, oxidation and erosion of the contacts. However, arcing can be minimized by utilizing materials for the sliding contacts which have a high work function. Such materials require a large work to extract an electron from the metal into the air, for example, due to an electric field. These electrons which are pulled into the air, in turn, ionize the air and thus promote arcing.

It may be assumed that with an applied voltage of 30,000 volts direct current, an arc will jump approximately one inch in air. Therefore, a voltage of 300 volts would ionize 0.01 inch in air. Thus, the arcing may further be minimized by providing a relatively small distance between the cooperating metal parts and by moving the switch at a relatively fast rate. With the materials used in the switch of the invention it has been found that substantially no arcing takes place when the applied voltage is 150 volts direct current and when the switch is moved at the rate of 0.020 inch every 0.5 millisecond. This rate of travel equals 40 inches per second. Obviously, if the switch is designed for low voltages, arcing becomes less of a problem.

It may be mentioned that in the push button switch illustrated in FIGS. 1 through 6, the pressure exerted by the contact springs 28 and 30 is 1.5 pounds. The contact area of the surface 68 is .05 square inch after some wear so that the contact pressure amounts to approximately 400

p.s.i. It may also be noted that the lubricating film provided over the contacting surfaces protects the contact surfaces from corrosion, oxidation or other chemical action. Generally, it is this corrosion, oxidation or formation of sulphur compounds which varies the contact resistance over the useful life of the switch. Furthermore, even if a film of oxide or other compound should form on the contact surfaces, this film is scraped off if a high contact pressure is used. For this reason, the movable contact elements, such as the extruded portion 67 should be made of some metal or alloy which readily abrades off or has a flaking action.

It is also feasible, in accordance with the present invention, to make the armature portion 57 of a thermosetting molding compound which is filled with Orlon fibers. Such a thermosetting compound may be an allylic resin based compound which is known as diallyl phthalate. The Orlon fibers serve as wicks to maintain at all times a lubricating film on the surface of the armature portion 57 and of the shorting clip 31.

It may also be pointed out that the contact springs 28 and 30 are preferably coil springs rather than leaf springs. Coil springs exhibit less fatigue than leaf springs and also have a larger spring force which is needed here. Furthermore, a coil spring is less apt to resonate or vibrate mechanically and exhibits less reaction to acceleration.

The push button switch of the present invention operates as follows:

The switch is normally open as shown in FIG. 1 which illustrates the switch in its unactuated position. Thus, the two contact elements 67 bear against the insulating armature portion 57. FIG. 6 illustrates the switch when actuated. By pressing the push button 24 against the action of return spring 25, the contacts 67 make electrical contact with the shorting bar 31. Accordingly, an electric circuit connected to the two terminal elements 26 and 27 through suitable conductors is now closed. Movement of the push button 24 may be arrested by shoulder 59 of projection 54 of the armature hitting the end of recesses 42, 43 in the housing.

It has been found that the push button switch of the present invention has a trouble-free life which exceeds one million cycles of operation. During the useful life of the switch, the contact resistance remains low and is not subject to change.

It is not necessary to have a single element which serves both as a terminal and a contact element. Such a construction is illustrated in FIG. 7 to which reference is now made. The switch illustrated in FIG. 7 is the same as that illustrated in FIGS. 1 through 6 except that a terminal element 72 only extends through the end cap 21 and is broken off within the housing 20. The terminal element 22 may again be provided with an aperture such as shown at 63 in FIG. 5 and with an upturned portion 64. It may also have a shoulder 65 for retaining the terminal element within the end cap 21. The contact element 73 may take the shape of a hollow, elongated cylinder as illustrated and may have a flat contact surface 74. A contact spring 28 is again provided in the recess 40 in the housing 20 to urge the contact element 73 against the armature portion 57. A suitable conductor 75 connects the contact 73 to the terminal element 72. The contact element 73 may be made of any of the materials previously described.

It may be noted that the advantage of the constructions illustrated in FIGS. 7 and 9 is that the contact element 73 or the contact button 71 being relatively small may be made of a rare and precious metal or alloy without substantially increasing the price of the switch.

FIG. 8 illustrates a switch in accordance with the present invention which is normally closed. The switch of FIG. 8 has the same construction as that shown in FIGS. 1 through 6, except that the shorting bar 31 is provided near the free end of the armature portion 57 so that the

contact elements 67 are normally in contact with the shorting bar 31 to close an electrical circuit connected to the two terminal elements 26 and 27. The electrical circuit may be opened by actuating or depressing the push button 24. Otherwise, the switch of FIG. 8 operates in the same manner as previously described and may be made of the same materials.

The push button switch of the present invention may be made quite small. Thus, the diameter of the housing 20 may be one-half inch while the diameter of the end fitting 22 may be three-eighths of an inch. The total length of the switch from the operating button 24 to the terminal fittings 27 or 26 is less than 1.5 inch.

A linear potentiometer is accordance with the present invention is illustrated in FIGS. 10 through 14. While the linear potentiometer has been described and illustrated herein, it is being claimed in the previously referred to copending application of Edwin F. Pierce entitled "Linear Potentiometer."

One embodiment of the linear potentiometer of the invention is illustrated in FIGS. 10 to 13 to which reference is now made. The potentiometer includes a housing 80, two end plates 81 and 82, a brush holder 83, a brush 84, an adjusting screw 85 which cooperates with a nut 86 and two contact springs 87 and 88. The potentiometer further includes a resistance element or rod 90 and a rod-shaped conductor 91 forming a common return connection.

As clearly shown in FIG. 12, the housing 80 is of generally rectangular cross section and has elongated, cylindrically shaped recesses 92 and 93 through which the resistive element 90 and the conductive element 91 extend. Rounded projections 94 and 95 of generally semicircular cross section may be provided about the circular recesses 92 and 93. The housing 80 may again be made of Lexan.

The end plates 81 and 82 may also consist of Lexan. The end plates 81 and 82 may be cemented or otherwise secured to the housing 80 and have an outline corresponding to the cross section of the housing 80. A central aperture 96 is provided in the end plate 81 for receiving the adjusting screw 85. Furthermore, the end plate 81 is provided with apertures 97 and 98 through which cable conductors 100 and 101 may extend. Similarly, the end plate 82 is provided with an aperture 102 for extending therethrough a cable conductor 103.

The adjusting screw 85 extends through the opening 96 in the end plate 81. The adjusting screw may have a suitable head 105 with a slot 106 for adjusting the screw, for example, by a screw driver. The adjusting screw 85 may be made of any suitable metal such, for example, as stainless steel which resists corrosion. A split washer 107 secures the screw to the end plate 81. To this end the screw preferably has a reduced portion in which the split washer 107 is mounted. Hence, the screw 85 is secured between its head 105 and the washer 107, both bearing against the end plate 81. The adjusting screw 85 is readily rotatable for adjustment thereof.

The brush holder 83 is made of any suitable insulating material, such as Lexan. The brush holder 83 has a rectangular central recess 108, clearly shown as in FIGS. 12 and 13 for receiving the nylon nut 86. The nut 86 is held from rotation in the recess 108. The lower portion of the brush holder 83 has two cylindrical recesses 110 for receiving the two contact springs 87 and 88 as shown in FIG. 12. Furthermore, extending across the lower portion of the brush holder 83, there is a rectangular recess 111 which receives the brush 84.

The brush 84 as shown in FIG. 12 is rectangular in side view while its cross section is curved as shown in FIG. 13 to provide a common contact surface both for the common return rod 91 and the resistive rod 90. The brush 84 may, for example, consist of the alloy nickel-silver which includes 18% nickel and 81% copper. Alternatively, the brush may consist of any material men-

tioned with respect to the terminal element 26 or the contact button 71. It will be noted that the two contact springs 87 and 88 exert a uniform, balanced pressure pressing the brush 84 with equal pressure against the rods 90 and 91.

The rod 90 may consist of any suitable resistive material such as carbon. As explained before, the rod 90 is received in the cylindrical recess 92 in the housing body 80. The rod 91 is received in a similar cylindrical recess 93 and consists of any conductive material. For example, the rod 91 may consist of copper or brass which has been plated with nickel. Alternatively, the common return rod 91 may consist of any material of which the return clip 30 may be made.

The resistive element or rod 90 may be connected in any suitable manner on both ends to a cable conductor 100 and 103 as shown. Thus, either the cable conductor 100 or the conductor 103 may be connected to an electric circuit. The return connection may be made through the cable conductor 101 which is electrically connected in any conventional manner to the return conductor 91.

In accordance with the present invention, a lubricating material of high dielectric constant is spread over both the resistive rod 90 and the conductive rod 91. Such a lubricating material may again consist of No. 871 Switch Lube. Preferably, again a light coat of the lubricant is spread over the contact surface of the brush 84 and the protruding surfaces of the resistive rod 90 and the conductive rod 91. The contact pressure should be large enough to break through the film of lubricant between the brush and the two contact elements 91 and 90 so that a metal-to-metal contact between the rod 91 and the brush 84 is obtained. Even higher contact pressures of the order of 100 to 1000 pounds per square inch may be obtained, if desired.

The potentiometer illustrated in FIGS. 10 through 13 operates as follows:

An electric circuit may be connected between the cable conductors 100 and 101. In that case, the resistance of the resistive element 90 between the cable conductor 100 and the brush 84 is in the electrical circuit. The electric current then travels from the resistive rod 90 through the brush 84 into the common return connection 91 and out through the cable conductor 101. Alternatively, it is also feasible to connect the electrical circuit between the cable conductor 103 and the conductor 101. In that case, the electrical resistance of the resistive rod 90 between the cable conductor 103 and the brush 84 is in the electrical circuit.

It will be noted that the adjusting screw 85 forms no part of the electrical circuit. The screw 85 is insulated from the electric circuit through the end plate 81 and through the brush holder 83 and the insulating nut 86. This arrangement has the advantage that any variable resistance which may be created between the brush and the adjusting screw 85 is eliminated.

The provision of the lubricating material of high dielectric constant again has all the advantages previously pointed out. Thus, the contact resistance remains low throughout the useful life of the potentiometer. Furthermore, the lubricant protects the surfaces of the brush 84, the metal rod 91 and the resistive rod 90 from corrosion, oxidation and other chemical action which might change their electric resistance. Any worn off metal particles are again imbedded in the lubricant such as No. 871 Switch Lube.

The electric resistance is adjusted, for example, by a screw driver inserted in the slot 106 of the head 105 of the adjusting screw. Alternatively, the adjusting screw 85 may be driven through an electric motor or rotated in any other conventional manner.

A modification of the resistive element 90 is illustrated in FIG. 14. Here, there is provided a cylinder 115 of insulating material having a helical groove 116 of substantially spherical cross section. A resistive wire 117 is

inserted into the helical groove 116 in such a manner that the surface of the wire 117 is substantially flush with the surface 118 of the cylinder 115. The lubricating material, such as No. 871 Switch Lube is provided and retained in the gap between the wire 117 and the helical recess 116. Thus, the brush 84 slides between each portion of the wire 117 and the insulating surface 118. Preferably, the wires 117 are so close together that the conductive surface of the brush 84 bridges two adjacent wires 117.

It may be noted that the carbon element or rod 90 has a porous surface for retaining the lubricant. Thus, each pore in the carbon element serves as a small wick to retain the lubricant by capillary action keeping the rod 90 well lubricated. The same applies to the pits in the nickel-plating of the return rod 91. In the resistive element of FIG. 14, the lubricant is retained in the space between the insulating cylinder 115 and the wire 117.

The advantage of the potentiometer illustrated in FIGS. 10 through 14 is again due to the provision of an insulating lubricant coupled with a relatively high contact pressure. This results in a low contact resistance and uniformity of the contact resistance throughout the operating life of the potentiometer. The construction of the potentiometer is simplified by the adjustment screw 85 and its nut 86. Furthermore, the housing 80, the end plates 81 and 82 and the brush holder 83 may be made of molded construction thus reducing the cost. The adjustment screw 85 is insulated from the electric circuit which promotes repeatability of the resistance for any particular position of the brush holder 83. Accordingly, the potentiometer can readily be calibrated and will not change its resistance throughout its useful life and furthermore, the resistance for each position of the brush holder 83 will always remain the same.

There has thus been disclosed an improved electromechanical device such as any switch including a relay having sliding contacts or a potentiometer with sliding contacts. The switches or potentiometers, in accordance with the invention are characterized by the provision of an insulating lubricant having high dielectric constant between the sliding contacts. In addition, the contact pressure is high enough to break through the lubricating film and to create a metal-to-metal contact. This construction considerably reduces the contact resistance and maintains the contact resistance constant throughout the operating life of the device. The lubricant protects the contact surfaces from chemical action which in turn promotes a low contact resistance. Any surface impurities or chemical compounds which may form on the surface may be simply rubbed or wiped off if the contact pressure is sufficiently high. This high contact pressure in turn produces better contact and eliminates arcing as well as the two or three spurious signals which are created due to bouncing or other effects of the switch contacts. If the contact pressure of the switch is high enough, it can be operated at high acceleration up to 100 g, where g is the acceleration of the earth. The switches will also operate under conditions of high vibration. Furthermore, the electromechanical devices of the present invention have a long operating life which may be counted in the millions of operating cycles. Throughout the operating life of the device, it retains its desirable characteristics without deterioration. On the other hand, the switch of the present invention is of simple construction and can be manufactured at a very low cost which does not exceed that of competitive switches.

The invention and its attendant advantages will be understood from the foregoing description. It will be apparent that various changes may be made in the form, construction and arrangement of the parts of the invention without departing from the spirit and scope thereof or sacrificing its material advantages, the arrangement hereinbefore described being merely by way of example. I do not wish to be restricted to the specific form shown

or uses mentioned except as defined in the accompanying claims, wherein various portions have been separated for clarity of reading and not for emphasis.

I claim:

1. An electromechanical device comprising:
 - (a) a first conductive contact element having a pitted contact surface;
 - (b) a second conductive contact element having a contact surface providing a flaking action;
 - (c) means providing sliding motion between said contact elements;
 - (d) a lubricant disposed between said contact elements and filling the pits in said first contact element to promote formation of a lubricant film on the first contact element, and said lubricant being electrically insulating and having a high dielectric constant and having a low surface tension; and
 - (e) means continuously acting upon one of said contact elements for urging said elements into contact with each other with a force in excess of that required to break through said lubricant film, whereby conductive particles worn off said contact elements during sliding motion thereof due to the contact pressure are imbedded in said lubricant and insulated from each other to prevent undesired short circuits between said contact elements.
2. A switch comprising:
 - (a) a first contact element having a conductive portion and an insulative portion, said conductive and insulative portions defining a pitted surface;
 - (b) a second conductive contact element fabricated of a material which flakes when slid against said pitted surface having a surface engaged with said pitted surface;
 - (c) means pressing said contact elements against each other with a predetermined contact pressure;
 - (d) means providing relative sliding movement between said contact elements, whereby said second contact element either contacts said conductive portion to make an electric circuit or contacts said insulative portion to break an electric circuit connected to said contact elements; and
 - (e) an insulating and lubricating material having a high dielectric constant and a low surface tension disposed between said first and second contact elements, said pitted surface of said first contact element serving to trap said lubricating material to promote formation of a lubricating film thereover, and said predetermined contact pressure being sufficient to brake through said lubricating film, whereby worn off conductive particles of said conductive portion of said first element and of said second element are imbedded in said lubricating material and insulated from each other and from said contact elements to prevent tracking.
3. A push button switch comprising:
 - (a) a housing of insulating material;
 - (b) a first member having a conductive portion and an insulative portion disposed adjacent to each other and providing a smooth outer surface, said first member being mounted in said housing for reciprocal movement therein;
 - (c) said housing being formed with a stop for limiting movement of said first member in one direction;
 - (d) first spring means disposed between said housing and said first member for urging said first member against said stop;
 - (e) two conductive contact elements adapted to be connected to an electric circuit for opening or closing the circuit;
 - (f) said conductive contact elements being disposed in said housing in substantially fixed relation to the first member and each having a portion slidably contacting simultaneously either said insulative or said conductive portion of said first member;

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- (g) an insulating lubricant of high dielectric constant disposed between said member and said contact elements for entrapping and entraining conductive particles worn from the first member and the contact elements in response to sliding motion therebetween for electrically insulating said particles from each other and from the first member and the contact elements; 5
- (h) two additional spring means, each being disposed between said housing and one of said portions of said contact elements for urging said contact element portions against said insulative and conductive portions of said member with a pressure at least great enough to break through a film of the lubricant between said member and said contact elements; and 10
- (i) a push button connected to said first member for actuating said first member against the force of said first spring means. 15
- 4. A push button switch comprising:
 - (a) a housing of insulating material; 20
 - (b) a first member of insulative material mounted in said housing for reciprocal movement therein, said first member having a recess extending about its circumference; 25
 - (c) a clip of conductive material disposed in the recess of said first member and providing a superficially porous outer surface essentially continuous with the adjacent surface portion of said member; 30
 - (d) said housing being formed with a stop for limiting movement of said first member in one direction; 35
 - (e) return spring means disposed between said housing and said first member for urging said first member against said stop; 40
 - (f) two conductive contact elements adapted to be connected to an electric circuit for opening or closing the circuit; 45
 - (g) said conductive contact elements being disposed in said housing and having each a portion contacting simultaneously either said conductive clip or said first member, said portions of the contact elements being fabricated of a material which flakes when slid against the outer surface of said clip to produce minute conductive particles; 50
 - (h) an insulating lubricant of high dielectric constant disposed between said clip and said contact elements for entrapping and encapsulating said conductive particles and insulating them from each other and from the clip and the contact elements to prevent short circuits between the contact elements and the clip when the contact elements engage said first member; 55
 - (i) two additional contact spring means, each being disposed between said housing and one of said portions of said contact elements for urging said contact element portions against said conductive clip or said member with a pressure sufficient to break through the lubricant film between said clip and said contact elements to make a conductive connection therebetween when the first member is disposed to place the clip in alignment with the contact elements; and 60
 - (j) a push button connected to said first member for pushing said first member against the force of said return spring means. 65
- 5. A push button switch adapted for on-off operation comprising:
 - (a) a substantially cylindrical housing of insulating material; 70
 - (b) an end cap of insulating material secured to said housing for closing one end thereof;
 - (c) a hollow end fitting disposed on the other end of said housing; 75
 - (d) two contact elements, each consisting of a flat metal strip extending through said end cap in spaced relationship and having an extruded hollow portion within said housing;

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- (e) an armature of insulating material extending through said end fitting and having a depending portion within said housing and having a push button extending beyond said end fitting for actuation thereof;
- (f) a stop member on said armature cooperating with said end fitting to limit movement of said armature in one direction;
- (g) a recess in said end cap;
- (h) a return spring disposed between said recess and said armature for urging the stop member in said armature against said end fitting;
- (i) two recesses in said housing disposed adjacent said hollow portions of said contact elements;
- (j) said depending armature portion having a C-shaped recess;
- (k) a metal clip in said recess of said armature and forming a substantially smooth surface with the remainder of said depending armature portion against which the outer surfaces of said hollow portions bear; and
- (l) a contact spring disposed between each of said recesses in said housing and one of said hollow portions of said contact elements to press said contact elements against either said insulating portion of said armature or against said metal clip by depressing or releasing said push button against the action of said return spring.
- 6. A push button switch adapted for on-off operation comprising:
 - (a) a substantially cylindrical housing of insulating material consisting of two substantially identical portions and having two spaced longitudinally extending recesses;
 - (b) means for securing said housing portions together;
 - (c) an end cap of insulating material secured to said housing for closing one end thereof;
 - (d) a hollow end fitting disposed on the other end of said housing;
 - (e) two contact elements, each consisting of a flat metal strip extending through said end cap in spaced relationship and having an extruded hollow portion within said housing;
 - (f) an armature of insulating material extending through said end fitting and having a depending portion within said housing and having a push button extending beyond said end fitting for actuation thereof, said armature having two projecting portions disposed in said longitudinal recesses of said housing to prevent rotation of said armature;
 - (g) a stop member on said armature cooperating with said end fitting to limit movement of said armature in one direction;
 - (h) a recess in said end cap;
 - (i) a return spring disposed between said recess and said armature for urging the stop member in said armature against said end fitting;
 - (j) two cylindrical recesses in said housing disposed adjacent said hollow portions of said contact elements;
 - (k) said depending armature portion having a C-shaped recess;
 - (l) a metal clip in said recess of said armature and forming a substantially smooth surface with the remainder of said depending armature portion against which the outer surfaces of said hollow portions bear; and
 - (m) a contact spring disposed between each of said cylindrical recesses in said housing and one of said hollow portions of said contact elements to press said contact elements against either said insulating portion of said armature or against said metal clip by depressing or releasing said push button against the action of said return spring.

7. A push button switch adapted for on-off operation comprising

- (a) a substantially cylindrical housing of insulating material,
- (b) an end cap of insulating material secured to said housing for closing one end thereof,
- (c) a hollow end fitting disposed on the other end of said housing,
- (d) two contact elements, each consisting of a flat metal strip extending through said end cap in spaced relationship and having a contact portion within said housing fabricated of a material which flakes when abraded to provide small conductive particles,
- (e) an armature of insulating material extending through said end fitting and having a depending portion within said housing and having a push button extending beyond said end fitting for reciprocal actuation of the armature relative to the housing,
- (f) means cooperating between the armature and the housing for preventing angular motion of the armature relative to the housing,
- (g) a stop member on said armature cooperating with said end fitting to limit reciprocal movement of said armature in one direction,
- (h) a recess in said end cap,
- (i) a return spring disposed between said recess and said armature for urging the stop member against said end fitting,
- (j) two recesses in said housing disposed adjacent said contact portions of said contact elements,
- (k) said depending armature portion having a C-shaped recess,
- (l) a metal clip in C-shaped recess and forming a minutely pitted surface essentially continuous with the remainder of said depending armature portion against which the outer surfaces of said contact portions bear,
- (m) an insulating lubricant of low surface tension and high dielectric constant disposed between the clip and said contact portions for encapsulating said conductive particles and insulating them from each other and from the clip and the contact portions, and
- (n) a contact spring disposed between each of said recesses in the housing and a respective one of the contact portions of said contact elements to slidably press said contact elements against the armature with sufficient force that the contact portions break through a film of said lubricant on the clip to make electrical contact therewith when said armature is positioned to align the clip with the contact portions,
- (o) reciprocal movement of the armature in the housing producing sliding movement between the clip and the contact portions for abrading the contact portions to produce said conductive particles.

8. A push button switch adapted for on-off operation comprising

- (a) a substantially cylindrical hollow housing of insulating material,
- (b) an end cap of insulating material secured to said housing for closing one end thereof,
- (c) a hollow end fitting disposed on the other end of said housing,
- (d) two terminal elements, each consisting of a flat metal strip extending through said end cap in spaced relationship,
- (e) an armature of insulating material extending through said end fitting and having a depending portion within said housing and having a push button extending beyond said end fitting for reciprocal actuation of the armature relative to the housing,
- (f) a stop member on said armature cooperating with said end fitting to limit reciprocal movement of said armature in one direction,
- (g) means cooperating between the armature and the

housing for preventing angular motion of the armature relative to the housing,

- (h) a recess in the end cap,
- (i) a return spring disposed between the end cap recess and the armature for urging the stop member against the end fitting,
- (j) two recesses in said housing opening toward the armature,
- (k) two contact elements, each being slidably disposed in a respective one of the housing recesses for movement toward the armature, the contact elements being fabricated of a material which flakes when abraded to produce small conductive particles,
- (l) a conductive connection between each contact element and a respective one of said terminal elements,
- (m) said depending armature portion having a C-shaped recess,
- (n) a metal clip in said C-shaped recess forming a minutely pitted surface essentially continuous with the remainder of said depending armature portion against which the outer surfaces of said contact elements bear,
- (o) an insulating lubricant of low surface tension and high dielectric constant disposed between the clip and the contact elements for encapsulating the conductive particles and insulating them from one another, and the clip and the contact elements,
- (p) a contact spring disposed between each of said recesses in said housing and the corresponding one of said contact elements to press said contact elements into slidable engagement with the depending portion of the armature with sufficient force to break through a film of said lubricant between the clip and the contact elements when the armature is disposed to align the clip with the contact elements,
- (q) reciprocal motion of the armature in the housing producing slidable movement of the clip relative to the contact elements to abrade the contact elements and thereby produce said conductive particles.

9. An electrical switch comprising a first member fabricated of electrically nonconductive material, a second member fabricated of electrically nonconductive material disposed adjacent the first member, means mounting the members for movement relative to each other, selectively operable means operatively connected to one of the members operable for moving the one member relative to the other member, contact means including a first metallic element carried by the first member and fabricated of a metal which has a pitted surface and a second metallic element carried by the second member and fabricated at least in part from a metal which flakes when abraded, an insulating lubricant disposed between the metallic elements, spring means biasing the second metallic element into engagement with the first member with a force sufficient to break through a film of said lubricant, the means mounting the members and the selectively operable means being cooperatively configured and arranged so that the metallic elements move slidably relatively to each other upon operation of the selectively operable means and so that the metallic elements move into and out of conductive engagement with each other upon sequential operation of the selectively operable means, the lubricant encapsulating and insulating from each other metallic particles worn from the metallic elements during slidable engagement and disengagement thereof.

10. An electrical switch comprising a first member fabricated of electrically nonconductive material and defining a surface, a second member fabricated of electrically nonconductive material disposed adjacent the first member, means mounting the members for movement relative to each other, selectively operable means operatively connected to one of the members operable for moving the one member relative to the other member,

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contact means comprising three metallic elements including first metallic element fabricated of a metal which has a pitted surface and mounted so that the pitted surface is substantially flush with the surface of the first member, a second metallic element carried by the second member and fabricated at least in part from a metal which flakes when abraded and a third metallic element similar to one of the first and second metallic elements and mounted similar to the one of the first and second metallic elements to which it is similar, an insulating lubricant disposed between the metallic elements, spring means biasing the metallic element carried by the second member into engagement with the first member and said surface thereof with a force sufficient to break through a film of said lubricant, the means mounting the members and the selectively operable means being cooperatively configured and arranged so that two of the metallic elements move slidably relatively to the third metallic element upon

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operation of the selectively operable means and so that the metallic elements move into and out of simultaneous conductive engagement with each other upon sequential operation of the selectively operable means, the lubricant encapsulating and insulating from each other metallic particles worn from the metallic elements during slidable engagement and disengagement thereof.

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