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(54) LOW THROW TOUCH OPERABLE ELECTRIC SWITCHES

(71) We, WILD ROVER CORPORATION, a corporation organized and existing under the laws of the State of New Jersey, located at 241 Herbert Avenue, Closter, New Jersey, U.S.A., do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to particularly described in and by the following statement:—

This invention relates to a low force, low throw, touch operated electric switch. It is directed particularly to providing a mechanical type, low force and throw, touch operated switch that is capable of carrying relatively large electrical currents and operating over many repeated applications without failure. The invention is also applicable to switches in general, and employs internal parallel and series type contact arrangements to aid in making and breaking an electrical circuit.

The invention has for a particular object the providing of a mechanical type switch which may be touch operated by the user with little or no sensation of actuation, that is, a switch involving a low throw and a low force for actuation. Touch operated switches have been employed in the past, many involving capacitance changes occasioned upon actuation. Most mechanical type switches are not truly touch operated, and the user experiences a definite sensation of actuation which is to be avoided in the present invention.

Conventional switches rely heavily in their design upon the practical necessity of high impact and retractile forces, respectively, during switch activation and deactivation, to create low resistance, to break welds that may be formed, and to clean the contacts. In the present invention a switch is provided which requires only gram-force for activation, e.g. in the neighbourhood of twenty or thirty grams. In this environment contact resistance and arcing must be reduced to a minimum by other factors. The basic nature of touch operation, however, limits the on-state contact resistance, power-handling capability, and ultimate life as compared with similar higher

force devices that are not touch operated. In the touch operation environment, the travel or throw, and hence the contact spacing in the off-state of the switch, must be sufficiently small to avoid the push-button feeling upon actuation to the on-state, and the movable contact must be relatively thin and lightweight to provide a soft spring action. The impact pressures upon contact are accordingly somewhat lower. Consequently, one can expect more of a problem in connection with contact contamination and build-up due to oxides or surface films. Less bulk material is available to absorb arc-hole burning and to accommodate the fine transfer of contact metal and electrical and mechanical wear and tear. Also to be expected are an increase in contact resistance and accompanying power dissipation, resulting in a heating of the contact elements, and a lower off-state breakdown voltage.

With all these constraints, touch operated switches in accordance with a preferred embodiment the invention are capable of suitable operation under activation of 20 to 30 grams, maintaining reliable operation over a million or so activations, exhibition of a 50 milliohm contact resistance, and embracing a voltage-ampere range covering several hundred volts and up to 15 amperes, for example.

The invention proceeds upon the basis that so called "touch" operation may be characterized by low force and low throw. A flexible-contact element is employed as the movable member in a switch, and includes a flexible portion providing flexibility and a contact-making portion that includes a plurality of parallel extended contact segments to make contact with a fixed base element of the switch. The deflection distance d (transverse) necessary to produce electrical contact between the contact segments and the base element is maintained less than about 0.008 inch. to provide low throw and inherent broad area contact. Further, the flexible portion of the flexible-contact element has a length L and a spring constant in an axial direction. The

dimension L is selected so that the ratio of the transverse distance d to the axial length L is less than about 0.02. If such a relationship between the distances d and L is maintained, there is an enhancement of the deflection in the transverse direction. In particular, if a transverse force Q is required to produce the transverse deflection d , the force Q is much less than would be required to produce the same deflection d in the axial direction. If the axial spring constant is selected to be appropriately "soft", such an axial spring constant coupled with the d to L relationship just mentioned effectively reduces the transverse force necessary to touch actuate the switch to produce electrical contact between the contact segments and the base contact to less than about 100 grams. It is in the region within which the distance d or throw is limited to less than about 0.008 inch and the force necessary to produce actuation of the switch is less than about 100 grams that "low force, low throw, touch operation" takes place.

The low throw utilized, as mentioned above, inherently provides a broad area contact between the contact-making portion of the flexible-contact element and the fixed base element. The broad area contact ensures parallel type operation since a plurality of extended conduction zones are responsible for the actual conducting of electrical current. The parallel operation is enhanced by the plurality of parallel and extended contact segments that form the contact-making portion of the flexible-contact element. Each segment may be considered to make a series of extended point contacts when the switch is actuated, and the plurality of segments thus constitute a group of extended point contacts or lines of contact in the switch. The broad area contact inherently produced results in good current distribution throughout all portions of the flexible-contact element, and current flow is not concentrated at a single point or zone as in many known switches.

Broad area contact is also enhanced by slightly bowing the flexible-contact element (concave toward the base element) so that as it is flexed into contact with the base element contact takes place over a wide area.

The low throw utilized in the switch necessarily results in a breakdown problem for normal electrical potentials encountered.

This problem is overcome by utilizing a plurality of series gaps in the switch itself so that the potential is divided among the gaps, effectively permitting a larger potential to be handled by the switch even though small gap spacings are utilized because of the low throw feature. For example, the flexible-contact element may be utilized to complete a plurality of series connections. The small gap accompanying each series connection is subjected to a smaller potential than the

overall potential handled by the switch, alleviating the breakdown problem which would otherwise be present.

The invention will be more completely understood by reference to the following detailed description of representative embodiments thereof. The drawings are described briefly as follows:

Fig. 1 is a simplified representation of a low force, low throw, touch operated switch in accordance with the invention.

Fig. 2 is a perspective view of a switch in accordance with the invention.

Fig. 3 is an exploded view showing the various parts of the switch of Fig. 2.

Fig. 4 is a bottom view of the switch of Fig. 2.

Fig. 5 is a sectional view to an enlarged scale of the switch of Fig. 4, taken along the section line 5-5.

Fig. 6 is an enlarged top view, partially broken away, of the switch of Fig. 2.

Fig. 7 is an enlarged sectional view of the switch of Fig. 6, taken along the section line 7-7.

Fig. 8 is a sectional view of another switch in accordance with the invention.

Figs. 9, 10 and 11 are simplified representations of series-parallel switching arrangements in accordance with the invention.

Figs. 12 to 26 are simplified representations of various flexible-contact elements in accordance with the invention.

Referring to Fig. 1, the principles of the invention are shown as embodied in a switch that includes a corrugated and electrically conductive flexible-contact element 30 including peaks 30a and 30b that lie substantially in two parallel planes. The element 30 includes inclined portions 30c at the axial ends thereof (each defining an angle b with the vertical) and inclined portions 30d intermediate the peaks 30a and 30b (each defining an angle c with the vertical). The ends of the element 30 are supported by insulating supports 32 which in turn rest upon a conductive base element 34. A terminal 36 is connected to the base element 34 and a terminal 38 is connected to the flexible-contact element 30. The element 30 is adapted to be actuated by an effective force Q applied thereto which deflects the element so that a plurality of the peaks 30b adjacent the base element 34 engage that base element.

The peaks 30b of the element 30 are spaced a distance d (in the y direction) from the base element 34. The length of the element 30 is designated L in the axial or X direction. For such an element, axial force P is related to axial deflection x in accordance with the following expression:

$$P = Kx \quad (1),$$

wherein k is the axial spring coefficient. If

the distance d is chosen relatively small so that the expression d/L is much less than unity, it can be shown that transverse deflection y is related to transverse force Q as follows:

$$\frac{y}{L} = \alpha \left(\frac{Q}{kL} \right)^{\frac{1}{3}} \quad (2).$$

Solving expression (2) for Q leads to the following expression:

$$Q = \alpha \left(\frac{k}{L^2} \right) y^3 \quad (3).$$

For a relatively small deflection wherein d/L is much less than unity, the force necessary to produce such a deflection is related by a constant $\frac{k}{L^2}$ to the cube of the deflection. The cube relationship provides an enhancement of deflection in the y direction when compared with the displacement that would be produced in the X direction in response to the same force. To explain, expression (2) above may be rewritten in the following form:

$$\frac{Q}{ky} = \left(\frac{y}{L} \right)^2 \quad (4).$$

The numerator Q represents the force applied in the transverse direction to produce a deflection y , while the denominator ky represents the spring force that would have to be exerted in the axial or X direction to give the same deflection y . The ratio of the two is a comparison of forces and is related to the square of the ratio $\frac{y}{L}$. It has been found

that the ratio $\frac{y}{L}$ for deflection d to actuate the switch should be generally less than 0.02. The square is 0.0004, indicating that the force Q needed to actuate the switch is indeed relatively small compared with the force needed to produce the same deflection d in the X direction.

The above expressions indicate the enhancement of deflection that is utilized in the present invention to provide "touch" operation in a switch. Referring again to Fig. 1, a relatively small actuation force Q applied against the element 30 results in sufficient deflection to make contact between the peaks 30b and the base element 34. Because of the relatively small distance of separation d between the peaks and base element, an inherent feature of the operation of the switch is that contact is made with the base

element almost over the entire area of the flexible-contact element 30. Thus the basic form of switch shown in Fig. 1 involves a broad area contact between switch elements. Contact is made between these elements through the plurality of peaks 30b. The peaks 30b constitute the contact-making portion of the element 30 and are electrically conductive segments providing parallel electrical contacts. The corrugations of the element 30 render that element flexible and constitute the flexible portion of that element. Each peak 30b provides a line of contact depending in extent upon the dimension of the element 30 in a direction perpendicular to the x and y directions in Fig. 1. Actually contact is made at a plurality of points in each "line", and hence the contact between each peak 30b and base element 34 may be considered to be an extended line of individual point contacts creating an extended zone of contact. The plurality of peaks 30b provide extended zones of parallel contacts, distributing the current carried by the switch throughout the zones and rendering relatively uniform the current distribution throughout the element 30. In conventional switches where contact is made only at a single point or at a few of such points, the current distribution is not uniform, and substantial welding between switch elements and burn-out and arcing-over may take place.

As the force Q is applied downwardly against the element 30 in Fig. 1 (the force Q is shown in Fig. 1 as a point force; this is an effective illustration of the force which need not be point applied but can be over the entire area of the element 30), substantially all of the peaks 30b substantially simultaneously contact the base element 34. Broad area contact is enhanced by bowing the element 30 (concave toward base element 34). Upon actuation in contact with the base element 34, the peaks 30b then readily lie in a plane and make good contact with the base element. There may be some sequential contacts made, but because of the plurality of peaks 30b involved, different combinations of peaks may contact the base element 34 at different times. In this fashion the paths of actual current flow may vary, from actuation to actuation, and in effect a random distribution of current paths is provided throughout the element 30. This aids in the life of the switch so that current flow is not limited to any particular zones of contact.

To explain the operation of the switch of Fig. 1 still further, when two nominally smooth flat surfaces are placed in apparent contact over a substantial area, it is well known that actual contact occurs only at a small number of microscopically small areas. Three of such points of area of contact are sufficient to locate the two surfaces. Thus only a small fraction of the available mechanical contact area electrically conducts in con-

ventional switches. The design of Fig. 1 utilizing the periodic, grating-line or corrugated shape, extended contact flexible element structure 30 to accomplish multiple-point conduction regions, utilizes a much larger portion of the apparent area of contact and is far superior to a single equivalent apparent area configuration. The switch involves approximately simultaneous or a systematic succession of timed impacts to decrease contact resistance and dissipation, distribute arcing, and to decrease mechanical wear and tear, material transfer and the like. In this construction a reasonable current capacity is achieved despite the low forces

involved, i.e. $R \propto \frac{1}{\sqrt{Q}}$, where R is the on-

state contact resistance, normally large for low Q. This is provided by the large total contact area. Since the contact is made by individual sections in parallel, a number of sections may exhibit defects in the making of contact, and yet the remainder carry the current overcoming the effects of such defects. For example, unpredictable contingencies can cause premature failure at a single section, that is, at one of the peaks 30b, such as severe localized arc transfer, burnout, or the lodging of a non-conductive dust particle not wiped away, any of which might cause the failure of a conventional type switch to complete a circuit. Such a problem simply reduces the effectiveness of the switch of Fig. 1 (for example, a 5% reduction) without impairing its basic utility. Performance of the switch will therefore not seriously deteriorate by virtue of the different numbers of peaks which can combine to make contact until many of such peaks fail.

As the spring element 30 is flexed, the peaks 30b move somewhat in the direction of the x axis because of the angular orientations b and c of portions of the element 30, causing a wiping action which tends to make good contact and also to break any welds that may be formed between the element 30 and the base element 34, as will be described in more detail below.

The switch of Fig. 1 provides a nonlinear mechanical touch mechanism using components and materials well within a reasonable linear design region (linear with respect to the x direction). As will be further explained, a range of distances d, pressure sensitivity and voltage and current ratings may be accommodated by varying a number of different physical parameters of the basic form of switch, as shown in Fig. 1, including the flexible-contact element material and thickness, the forming technique, the angles b and c, external mechanical connections, and the number and size of the extended contact sections or peaks 30b. Pressure sensitivity variations, from switch to switch, render the

basic form of switch suitable as a pressure transducer, for example, in each case set to be actuated to complete a circuit in response to a given applied force.

The open circuit contact separation such as the separation d in Fig. 1 and the anchor tab angle (b in Fig. 1) are critical in determining the activation pressure required to actuate the switch. The gap distance d is normally held to between 0.0025 to 0.004 inch, but may be as large as 0.008 inch. The short travel avoids the feeling of actually depressing the switch to actuate it and thus gives a sensation of simply touching the switch. The anchor tab angle is important: the force required to actuate and the ability of the flexible-contact element 30 to return to its original gap d can be controlled by adjusting the anchor tab angle as well as the dimensions and material properties of the flexible conductor itself. The spring return of this flexible conductor also helps to overcome any "make" or "break" welding which may take place, along with the rolling and sliding, that is, the wiping action just discussed. The greater the anchor tab angle, the less the actuation pressure which is required, also decreasing the gap distance d and return forces generated.

The design has been found to improve in efficiency with use, the contact points tending to burn themselves into full alignment, thus giving true multiple if not simultaneous contact.

Fig. 2 is a perspective view of a switch incorporating the principles of the invention. Referring to this Figure and also to Fig. 3, which is an exploded view of the switch showing all of its parts, the switch includes a housing 40 containing bores 42 and 44 therein. A pair of base or terminal elements 46 and 48 are positioned in the bores. Typically these terminal elements are moulded in place when the housing 40 is moulded. The housing 40 is advantageously of plastic. A metallic ring 50, such as of aluminium, serves as a heat sink and also as a supporting surface for the edges of a flexible-contact element 52. The element 52 comprises a plate 52a (slightly bowed) which serves as the flexible portion of the element. A plurality of wires 54 are affixed to the plate and constitute the contact-making portion of the element 52 and serve to contact the terminal elements 46 and 48. A disc 56 (e.g. a phenolic resin disc) is positioned over the flexible-contact element 52, and a clear film 58, such as of Mylar (Registered Trade Mark), completes the components of the switch.

Figs. 4 to 7 show the details of the completed switch shown in Fig. 2. The ring 50 is positioned within a groove 50a in the housing 40. The ends of the flexible-contact element 52 rest on the ring 50 as shown in Fig. 6. So that the element 52 may be maintained in position in the switch, the

corners thereof are maintained within grooves 60 (see also Fig. 3). When the element 52 is placed on the ring 50, the wires 54 affixed to the underside of the spring element are positioned over the terminal elements 46 and 48.

In fabricating the unit, as was noted above the terminal elements 46 and 48 are typically molded in place. The ring 50 is typically positioned first, followed by the positioning of the element 52 with wires 54. Next the disc 56 is positioned, followed by the clear film 58. The entire switch is then closed by bending over a rim 40a of the housing so that the rim assumes the position shown in Figs. 4 and 7, maintaining the sandwich of element 52, disc 56 and film 58 in place.

As shown in Figs. 4 and 5, the base or terminal elements 46 and 48 include screws 70 and 72 therein for the purpose of securing electrical conductors 76 and 78 to these elements. The electrical conductors may be positioned in grooves 80 and 82 in the housing 40.

Typical dimensions for the switch just described might be a diameter of about one inch and a depth of about 0.300 inch. The spacing between conductors or wires 54 on the bottom of the element 52 and the top surfaces of the terminal elements 46 and 48 might be in the order of 0.004 to 0.005 inch. The element 52 might be made of brass, roughly 0.002 inch thick, and the wires 54 advantageously may be made of silver cadmium oxide, 0.009 to 0.017 inch in diameter (totalling 8 in number in a representative embodiment and spaced 0.050 inch apart). The ring 50, which has been described as serving also as a heat sink, may comprise an aluminium ring 0.050 inch thick. The thickness will vary according to the gap desired between the top surfaces of the terminal elements 46 and 48 and the wires 54. In this regard, it will be noted from Fig. 7 in particular that the ring 50 spaces the surface of the element 52 a small distance away from a surface 40b of the housing. The surface 40b acts as a stop limiting the displacement of the spring element 52 so that if an excessive force Q is applied to the spring element, excessive deflection will not result.

The terminal elements 46 and 48 may be made of brass with a silver cadmium oxide contact surface at the top thereof, such as the surface 48a shown in Fig. 7.

The switch just described utilizes low force and low throw to give true mechanical touch operation as described above. The element 52 is typically slightly bowed (concave downwardly - see Fig. 7) to aid in the switch action. There are no compound curves in the element, so that the wires 54 are straight. This embodiment of switch can typically be run up to approximately 3 amps at 117 volts A.C. line voltage.

The spring element has a spring coefficient k in an axial or x direction, and the gap d between the wires 54 and the upper surface of the terminal element 48 is chosen small so that the force Q needed to complete contact within the switch is related to the cube of the deflection, as noted above.

One of the advantages of the switch of Fig. 6 is that a relatively good flexible material such as brass for the flexible element may be employed, while a relatively good contact material such as silver cadmium oxide may be utilized as to the actual contact-making element. Thus the flexibility characteristic is essentially provided by one material, and the electrical current carrying characteristic is supplied by another, more suitable material.

A difficulty with conventional contact switches and a problem presenting itself in the switches of Figs. 1 and 6 is that of spurious "on" failure, i.e., an electrical short condition at one or more sections of the switch. To overcome this deficiency and concomitantly to counteract the problem of a low voltage breakdown introduced by the necessarily low spacing of the switch elements, the invention involves a multiple series gap technique. In particular, it will be noted that in the switch of Fig. 6 there is a first group of contact gaps, between the terminal element 46 and the group of wires 54, and a second group of contact gaps, between the group of wires 54 and the terminal element 48, which must be closed in order to complete an electrical connection between the terminal elements. A integral series-parallel multiple break action is thus provided. Two basic series gaps exist between the two terminal elements and the group of wires; the parallel arrangement is achieved by the electrically parallel connected wires 54, each of which corresponds to one of the peaks 30b in the basic switch construction of Fig. 1. What is achieved is a series division of any arc among the individual series connected segments of the switch, that is, between the terminal element 46 and one or more of the wires 54 and between one or more of the wires 54 and the terminal element 48. The probability of bridging the two basic series gaps simultaneously is greatly enhanced by the internal parallel construction utilizing peaks 30b or wires 54. The number of combinations possible for the bridging of the two terminal elements 46 and 48 by the wires 54 is N^2 , where N is the number of wires 54, assuming plate 52a is of conductive material. It will be noted then that any number of wires less than N may fail to make contact, while others of the wires complete the connection, and the switch thus continues to operate. Essentially then the series-parallel arrangement has substantially reduced the arc voltage within the switch, simultaneously eliminated the possibility of spurious "on"

failure, and effectively multiplied the "off" state gap or net recovery voltage of the switch to avoid breakover due to line transients, while maintaining the short throw, e.g. 0.004 inch, necessary for true touch operation.

The theory explaining the behavior of multiple interruptions predicts not only that the multiple gap arrangement is much more effective than a single gap of equivalent width, even when produced at a corresponding speed, but that the arc duration itself is reduced by as much as 50% by increasing the number of breaks or gaps. It is seen then that the overall internal series-parallel mode reduction of arcing is substantial, and represents a reduction of non-useful and harmful switching energy.

The flexible-contact element combination of flexible element 52 and wires 54 of Fig. 6 exhibits pronounced wiping and rolling action upon touch activation along with enhanced impact pressures due to the sharp curvature of the actual wire and contact segments.

Fig. 8 shows a modified form of switch involving a housing 80 that is threaded as at 80a. The housing includes two base or terminal elements 82 and 84 shown in Fig. 9. The terminal elements typically include studs 86 and 88 threaded thereto for making electrical contact with the terminal elements. A corrugated flexible-contact element 90 including wires 92 at the bottom peaks thereof is positioned over the base elements 82 and 84. In Fig. 9 the wires 92 have been shown in dotted line to indicate the relative positioning between wires and base elements.

The ends of the element 90 are maintained in place by a ring 94. Upturned flange 94a of this ring serves as a stop against which a stabilizer plate 96 bears to limit the travel of the element 90 to avoid damage to the switch. The stabilizer plate is in turn actuated by an actuator plate 98 carried by a spring 100 that rests upon the ring 94. A further ring 102 maintains the spring 100 in place. An outer shell 104, internally threaded, threads onto the externally threaded housing 80 to complete the construction of the switch.

To actuate the switch the actuator plate 98 is touched. This plate communicates with the stabilizer plate through projection 98a to provide essentially a point application of force at the center of the stabilizer plate. The element 90 is moved downwardly so that the wires 92 contact the terminal elements 82 and 84 as in the switch of Figs. 1 to 7 described above.

The stabilizer plate effectively changes the characteristics of the flexible-contact element, as will be described in more detail below, depending upon how the plate is attached or secured to the element.

Fig. 9 shows the relationship between wires 92 and base or terminal elements 82 and 84.

This figure illustrates a series-parallel contact arrangement which is the same as the series-parallel arrangement in the switch of Figs. 1 to 7, namely, the wires 92 complete the series circuit between series connected terminal elements 82 and 84. The wires 92, however, form parallel connections between these terminal elements. An alternative arrangement is shown in Fig. 10 which utilizes a more involved series arrangement. In Fig. 10 base elements 110 and 112 are utilized as well as an intermediate base element 114. Parallel connected wires 116 carried by a flexible-contact element such as that shown in Fig. 3 are brought into contact with the base elements 110 and 112 and intermediate base element 114. If the base element 110 is an input terminal and the base element 112 is an output terminal, the wires complete an electrical circuit between the two terminals by forming one connection between the elements 110 and 114 and another connection between the elements 114 and 112. The additional series arrangement distributes the voltages across the many gaps that are formed in order to reduce the effects of arcing and the like as described above.

Fig. 11 shows another arrangement involving four separate base elements 120, 122, 124 and 126. A first group of parallel positioned end electrically connected wires 128 is positioned to contact the base elements 120 and 122, while a second group of parallel positioned and electrically connected wires 130 is positioned to contact the base elements 124 and 126. Typically, the two groups of wires are insulated from each other, but they may be carried by a single flexible element (not shown). The arrangement in Fig. 11 is suitable as a single pole switch, for example, in which case the base elements 120 and 126 might constitute input and output terminals respectively. The base elements 122 and 124 would be electrically connected together. Upon actuation of the switch moving the wires 128 and 130 against the respective base elements, connections are completed as follows: wires 128 bridge base elements 120 and 122; base element 122 is connected to base element 124; wires 130 bridge base elements 124 and 126 to couple the input signal at base element 120 to output base element 126. It will be noted that a multiplicity of gaps is provided between wires and base elements, as explained above in connection with Figs. 9 and 10, while parallel operation is achieved through parallel connected wires 128, 130.

Multiple pole operation is also possible in the switch arrangement of Fig. 11. In this case all base elements would be electrically insulated from each other; wires 128 would be insulated from wires 130. Base elements 120 and 126 might constitute input terminals while base elements 122 and 124 might constitute output terminals. Input signals

coupled to the input base elements 120 and 126 would be coupled respectively by the wires 128 and 130 to the respective output base elements 122 and 124.

5 It will be noted then that the invention involves a switch which can be single pole or multi pole. Depending upon the number of base elements and flexible-contact elements employed, an operation of "m" input poles and "n" output poles may be achieved. Groups of wires might be separately actuatable as carried by separate flexible elements, or more than one group might be carried by a common flexible element.

10 Figs. 12 to 14 show various arrangements of flexible-contact elements and stabilizer plate such as in the embodiment of Fig. 8. In Fig. 12, for example, element 140 includes wires 142 at the lower peaks of the corrugated element. Stabilizer plate 144 is secured to a plurality of the upper peaks. In Fig. 12 the stabilizer plate is secured to the two end peaks and to a middle peak. In Fig. 13 the stabilizer plate is secured only to the two middle peaks, and in Fig. 14 the stabilizer plate is secured only to the two end peaks. Depending upon the number of peaks to which the stabilizer plate is secured, the stiffness of the element 140 will vary, varying the touch characteristics of the switch.

15 Fig. 15 shows an alternative arrangement involving a flexible-contact element 150 which includes a spring material 151 and a cladding 152 of conductive material. Thus the flexibility function may be divided, and essentially provided by the material 151, while the conduction function is provided by the cladding 152.

20 Fig. 16 is another form of flexible-contact element and stabilizer plate in which insulating segments 160 space the lower peaks of the flexible-contact element from base element 162.

25 Figs. 17-26 show alternative forms of flexible-contact elements. In Fig. 17 element 160 includes a corrugated section 162 and non-corrugated sections 164 and 166 which take the form of horizontal portions. The horizontal portions 164 and 166 render the structure softer than would be the case of the corrugated portion 162 were continuous from one end of the structure to the other end of the structure.

30 Fig. 18 shows another flexible-contact element 170 which includes two corrugated sections 172 and 174 and an intermediate inverted V-shaped structure 176. The central inverted V-shaped structure 176 provides for sidewise movement of wires 178 attached to the peaks of the element.

35 Fig. 19 shows another element 180 in which the corrugated portion extends from one end of the element to the other. Wires 182 are attached to every other peak 184. The intermediate peaks 186 may be somewhat flat

shaped to give a sliding action to the wires when the element is actuated.

Fig. 20 shows a further flexible-contact element 200 involving a corrugated structure that includes peaks 202 lying in a first plane peaks 204 lying in a second plane and peaks 206 and 208 lying in a third plane. Peaks 206 have wires 210 affixed thereto. The structure of Fig. 20 involves a higher packing density of the wires 210 with respect to the structure of Fig. 19. Further, the use of the intermediate somewhat smaller peaks 204 provides more lateral movement than in the structure of Fig. 19 and also renders the action somewhat softer. An actuator or stabilizer plate 212 is shown in dotted line in Fig. 20 and is positioned against the peaks 202, indicating that actuation of the element takes place through these peaks lying in the first plane.

Fig. 21 shows another form of flexible-contact element 220. In this structure wires 222 are included to make electrical contact with a base element (not shown), and there are two of such wires for each contact zone of the element. Each pair of wires is affixed to a horizontal flat portion 224. The element involves an anchor tab angle b by which ends 226 of the flexible-contact element proceed into the interior part of the element. The interior part of the element also includes other angular orientations of portions thereof, such as represented by the angles e , f , g and h . The intermediate angular orientations of various portions of the switch affect the lateral movement of the wires 222 and also have an effect on the touch properties of the element.

Fig. 22 shows another flexible-contact element 230 in which the contact function and the flexibility function are essentially separated. Corrugated sections 232 and 234 are included at the ends of the element to provide the needed flexibility and spring action. The contact function is provided in the mid portion of the element by wires 236 which are rigidly supported by rigid intermediate plate section 238.

The structure of Fig. 23 is similar to the structure of Fig. 22, except that provision is made for a sequential action, and further, the electrical contact function is not carried simply by the mid portion. Element 240 of Fig. 23 includes corrugated end portions 242 and 244 and a mid portion 246 which is substantially rigid to which is affixed wires 248. The upper peaks 250 of the corrugated sections lie in a single plane. The lower peaks of the corrugated sections lie in different planes, however. For example, considering the corrugated section 244, one of the lower peaks 252 lies in a first plane, another lower peak 254 lies in a second lower plane, and a third lower peak 256 lies in yet another lower plane. The peaks 252, 254 and 256,

respectively, carry wires 258, 260 and 262. These latter wires are spaced different distances from a base element (not shown), and the wires sequentially make contact with the base element as the flexible-contact element 240 is actuated. Specifically the wire 262 first makes contact; contact is next made by the wire 260, and finally, wire 258 makes contact in this group of three wires. The wires of the element may be made of different materials, for example, so that initial contact is made first with one relatively tough material that provides good arc suppression, and succeeding contacts are made with softer lower contact resistance materials.

Fig. 24 illustrates another flexible-contact element 270 involving corrugated end portions 272 and 274, a corrugated portion 276 in the groups of wires 282 and 283. Spring action central region of the element, and intermediate rigid portions 278 and 280. The rigid portions 278 and 280 have groups of wires 282 and 283 attached thereto, adapted to make contact with base elements 284 and 286 shown in dashed lines. The material of the element 270 should be conductive to provide a conductive path between the two is essentially from the side corrugated sections 272 and 274, while the central corrugated section 276 provides essentially a wiping action (lateral movement of the groups of wires 282 and 283) as well as an electrical connection between these two groups of wires.

Fig. 25 shows a flexible-contact element 290 similar to the element 230 of Fig. 22. In this case the wires 236 of Fig. 22 are replaced by a corrugated and flexible contact-making element 292 which is affixed to rigid plate section 294 of the element. Corrugated end sections 296 and 298 correspond respectively to corrugated end sections 232 and 234 in Fig. 22. A further change is made in Fig. 25, however, in that some of the upper peaks of the corrugated end sections are flat topped, as at 300, while two peaks are rounded as at 302. The peaks 300 and 302 are at different heights, and an actuator or stabilizer plate (not shown) would bear against the higher peaks 302. The touch properties of the element 290 of Fig. 25 would therefore differ from the touch properties of the element 230 of Fig. 22. There is more lateral or wiping action in the structure of Fig. 25 by virtue of the flat topped peaks 300.

Finally, Fig. 26 shows a flexible-contact element 310 similar to the element 270 of Fig. 24. The element 310 includes corrugated end portions 312 and 314 and two intermediate rigid portions 316 and 318 separated by a single peaked flexible and conductive contact-making corrugated elements 322 and 324 each like the element 292 of Fig. 25. The essential difference from the structure of Fig. 24 is that the groups of wires 282 and 283 have been replaced by flexible contact-

making elements 322 and 324. The corrugated central section 276 in Fig. 24 is replaced by the single peaked section 320 in Fig. 26. Further, in Fig. 26 the upper peaks of sections 312 and 314 are at different heights (they are of the same height at the ends in Fig. 24) and all the peaks are flat topped (they are round topped in Fig. 24). Because of the different peak arrangements a somewhat different touch action is produced by the structure of Fig. 26 with respect to the structure of Fig. 24.

The above forms of flexible-contact elements are illustrative of different structures that may be utilized to provide touch operation in a switch. In the embodiment disclosed generally rectangular elements have been employed. It is possible to use circular flexible-contact elements, for example, as long as the requisite low throw and low force requirements are met.

In summary, the requirements of touch operation involve these basic aspects: (a) low throw, less than about 0.008 inch and generally around 0.004 inch, to avoid the feel of push and to give concomitant broad area contact in the switch;

(b) selection of effective axial dimension L of the flexible portion of the contact element so that the ratio of throw d to L is less than about 0.02, so as to be within the region of operation in which deflection force Q is related to the cube of the throw, ensuring enhanced deflection in the throw direction as compared with deflection in the axial direction;

(c) selection of axial spring constant k so that combined with the relationship between d and L distances a reduced transverse force necessary to touch actuate the switch is obtained and is less than about 100 grams, preferably around 20 to 30 grams;

(d) bowing of the flexible-contact element so as to give effective, broad area contact;

(e) providing linear, electrically parallel contact segments to ensure effective current distribution;

(f) employing multiple series gaps to reduce arcing tendencies and the like and to enable higher potentials to be encountered than usual with small gaps by distributing the overall potential among a plurality of gaps;

(g) employing configurations to aid in wiping, weld breaking and preventing, and to enhance touch operation.

WHAT WE CLAIM IS:—

1. A low throw, touch operable electric switch, comprising a flexible-contact element having a flexible portion of length L and an electrical contact-making portion, said contact-making portion comprising a plurality of spaced-apart linear contact segments, said flexible portion having a spring constant in an axial direction while being touch operable in a transverse direction, and a base contact

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respectively, carry wires 258, 260 and 262. These latter wires are spaced different distances from a base element (not shown), and the wires sequentially make contact with the base element as the flexible-contact element 240 is actuated. Specifically the wire 262 first makes contact; contact is next made by the wire 260, and finally, wire 258 makes contact in this group of three wires. The wires of the element may be made of different materials, for example, so that initial contact is made first with one relatively tough material that provides good arc suppression, and succeeding contacts are made with softer lower contact resistance materials.

Fig. 24 illustrates another flexible-contact element 270 involving corrugated end portions 272 and 274, a corrugated portion 276 in the groups of wires 282 and 283. Spring action central region of the element, and intermediate rigid portions 278 and 280. The rigid portions 278 and 280 have groups of wires 282 and 283 attached thereto, adapted to make contact with base elements 284 and 286 shown in dashed lines. The material of the element 270 should be conductive to provide a conductive path between the two is essentially from the side corrugated sections 272 and 274, while the central corrugated section 276 provides essentially a wiping action (lateral movement of the groups of wires 282 and 283) as well as an electrical connection between these two groups of wires.

Fig. 25 shows a flexible-contact element 290 similar to the element 230 of Fig. 22. In this case the wires 236 of Fig. 22 are replaced by a corrugated and flexible contact-making element 292 which is affixed to rigid plate section 294 of the element. Corrugated end sections 296 and 298 correspond respectively to corrugated end sections 232 and 234 in Fig. 22. A further change is made in Fig. 25, however, in that some of the upper peaks of the corrugated end sections are flat topped, as at 300, while two peaks are rounded as at 302. The peaks 300 and 302 are at different heights, and an actuator or stabilizer plate (not shown) would bear against the higher peaks 302. The touch properties of the element 290 of Fig. 25 would therefore differ from the touch properties of the element 230 of Fig. 22. There is more lateral or wiping action in the structure of Fig. 25 by virtue of the flat topped peaks 300.

Finally, Fig. 26 shows a flexible-contact element 310 similar to the element 270 of Fig. 24. The element 310 includes corrugated end portions 312 and 314 and two intermediate rigid portions 316 and 318 separated by a single peaked flexible and conductive contact-making corrugated elements 322 and 324 each like the element 292 of Fig. 25. The essential difference from the structure of Fig. 24 is that the groups of wires 282 and 283 have been replaced by flexible contact-

making elements 322 and 324. The corrugated central section 276 in Fig. 24 is replaced by the single peaked section 320 in Fig. 26. Further, in Fig. 26 the upper peaks of sections 312 and 314 are at different heights (they are of the same height at the ends in Fig. 24) and all the peaks are flat topped (they are round topped in Fig. 24). Because of the different peak arrangements a somewhat different touch action is produced by the structure of Fig. 26 with respect to the structure of Fig. 24.

The above forms of flexible-contact elements are illustrative of different structures that may be utilized to provide touch operation in a switch. In the embodiment disclosed generally rectangular elements have been employed. It is possible to use circular flexible-contact elements, for example, as long as the requisite low throw and low force requirements are met.

In summary, the requirements of touch operation involve these basic aspects: (a) low throw, less than about 0.008 inch and generally around 0.004 inch, to avoid the feel of push and to give concomitant broad area contact in the switch;

(b) selection of effective axial dimension L of the flexible portion of the contact element so that the ratio of throw d to L is less than about 0.02, so as to be within the region of operation in which deflection force Q is related to the cube of the throw, ensuring enhanced deflection in the throw direction as compared with deflection in the axial direction;

(c) selection of axial spring constant k so that combined with the relationship between d and L distances a reduced transverse force necessary to touch actuate the switch is obtained and is less than about 100 grams, preferably around 20 to 30 grams;

(d) bowing of the flexible-contact element so as to give effective, broad area contact;

(e) providing linear, electrically parallel contact segments to ensure effective current distribution;

(f) employing multiple series gaps to reduce arcing tendencies and the like and to enable higher potentials to be encountered than usual with small gaps by distributing the overall potential among a plurality of gaps;

(g) employing configurations to aid in wiping, weld breaking and preventing, and to enhance touch operation.

WHAT WE CLAIM IS:—

1. A low throw, touch operable electric switch, comprising a flexible-contact element having a flexible portion of length L and an electrical contact-making portion, said contact-making portion comprising a plurality of spaced-apart linear contact segments, said flexible portion having a spring constant in an axial direction while being touch operable in a transverse direction, and a base contact



- element spaced transversely a distance d from said contact segments in the non-contacting position of said flexible-contact element and contacted in operation by said contact segments upon transverse deflection of said flexible portion from said non-contacting position; and the distance d being less than 0.008 inch and the distance L being such that the ratio d/L is less than 0.02, so that in moving to the closed-circuit condition of said switch broad area arc distribution and eventually electrical contact take place between said contact segments and said base contact.
2. A switch as claimed in claim 1, constituting a low force, touch operated switch wherein the axial spring constant is such that the transverse force necessary to touch actuate the switch to produce electrical contact between said contact segments and said base contact is less than 100 grams.
3. A switch as claimed in claim 1 or claim 2, including two base elements contacted in operation by said contact segments, said contact segments thereby completing parallel electrical connections between said two base elements.
4. A switch as claimed in any one of the preceding claims, in which said flexible-contact element comprises a bowed plate and a plurality of wires secured to said plate.
5. A switch as claimed in claims 3 and 4, in which said two base elements are mounted in a housing, and including a metallic ring constituting a heat sink encircling said base elements for supporting said plate along opposite edges thereof.
6. Switch as in claim 5 in which a surface of said housing acts as an abutment for engaging said plate to limit and to prevent excessive transverse movement of said plate.
7. Switch as in any of claims 1—3 in which said flexible-contact element comprises a corrugated plate.
8. Switch as in claim 7 in which peaks of said corrugated plate adjacent to said base element constitute said contact segments.
9. Switch as in claim 7 in which peaks of said corrugated plate adjacent to said base element carry wires which constitute said contact segments.
10. Switch as in claim 7 in which said corrugated plate comprises a spring material clad with a contacting material.
11. Switch as in claim 7 in which said corrugated plate includes peaks lying in a plurality of planes.
12. Switch as in claim 11 in which adjacent one of said peaks define an inclined plane, so that said adjacent peaks contact said base element sequentially as said flexible-contact element is actuated.
13. Switch as in claim 12 in which adjacent one of said peaks are made of different materials.
14. Switch as in any one of claims 11—13 in which a plurality of said peaks adjacent to said base element abut against insulating members resting upon said base element.
15. Switch as in any one of claims 11—14 including a stabilizer plate bearing against those peaks furthest away from said base.
16. Switch as in claim 15 in which said stabilizer plate is secured to a plurality of the peaks against which it bears, the number of peaks to which said stabilizer plate is secured determining the stiffness of the flexible-contact element.
17. Switch as in claims 15 or claim 16 including an actuating member bearing against said stabilizer plate, said actuating member being actuated to actuate said switch.
18. Switch as in claim 17 in which said actuating member comprises a plate bearing against said stabilizer plate.
19. Switch as in claim 18 in which said actuating member is spring mounted to a housing that supports all the elements of said switch.
20. Switch as in any of claims 1—3 in which said flexible portion includes inclined portions which, when the switch is actuated, cause axial deflection of said contact segments so that said segments wipe over said base element.
21. Switch as in claim 20 in which said inclined portions are at the edges of said flexible portion.
22. Switch as in claim 20 in which said inclined portions are intermediate the edges of said flexible portion.
23. Switch as in any one of claims 1—3 in which said flexible-contact element comprises a plate which is corrugated at edges thereof for flexibility and which includes a rigid section in an intermediate portion thereof, said rigid section carrying another corrugated plate of which peaks thereof constitute said contact segments.
24. Switch as in any of claims 1—3 wherein said contact segments extend over a limited distance in the axial direction such that substantially all of said contact segments are brought into electrical contact with said base element or elements upon touch actuation by the finger of a user.
25. Switch as in claim 1 or claim 2 including a plurality of base elements that together with said contact-making portion define a plurality of electrical series connected gaps, said plurality of contact segments being electrically connected together and bridging

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each gap in an electrical parallel sense in the actuated state of the switch.

26. A low throw electric switch substantially as hereinbefore described with reference to the accompanying drawings.
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MICHAEL BURNSIDE & COMPANY,
Chartered Patent Agents,
36 Westminster Palace Gardens,
Artillery Row, London, S.W.1.
Agents for the Applicants

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