United States Patent

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[54] SWITCH WITH PARTICULAR TRANSVERSE DEFLECTION CHARACTERISTICS AND MOVABLE CONTACT PLATE WITH CONTACT MAKING WIRES ATTACHED
42 Claims, 26 Drawing Figs.

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[51] Int. Cl. H01h 1/06, H01h 1/26, H01h 13/52
[50] Field of Search .... 200/159, 159 A, 159 B, 5, 166.1, 5 C, 86, 83.8, 166 B, 166 F, 164, 166

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ABSTRACT: A low force, low throw, touch operated switch comprising at least one flexible-contact element having a flexible portion and an electrical contact-making portion that is to be deflected into contact with at least one base element. The flexible portion has an effective dimension L and an equivalent spring constant in an axial direction. The contact-making portion is separated by a distance *d* from an associated base element which is chosen to be less than about 0.008 inch to provide low throw in the switch and to ensure substantially simultaneous and broad area electrical contacting and arc distribution between contact-making portion and base element. The length L is also selected so that the ratio *d*/L is less than about 0.02, so as to enhance the transverse deflection. The switch is rendered a low force device by selection of the equivalent axial spring constant so that with the *d* to L relationship just-mentioned the transverse force necessary to touch actuate the switch to produce electrical contact between the contact making portion and the associated base contact is less than about 100 grams. Parallel contact operation for suitable current division is achieved through the use of a plurality of parallel and extended contact segments that constitute the contact-making portion of the element. Series gaps are utilized to aid in arc suppression and making and breaking of the electrical circuit by including the flexible-contact element as an intermediate element making contact with a plurality of base elements. A corrugated flexible-contact element structure is included to provide good spring action and to achieve a wiping effect to break welds that may be formed during contact closure. The flexible-contact element structure may be provided by a bowed plate with wires affixed thereto.

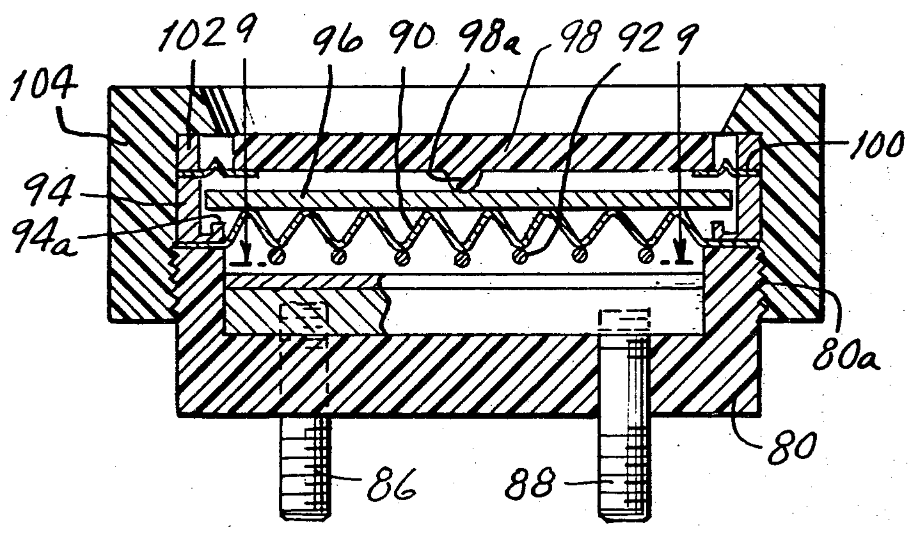


Fig.1

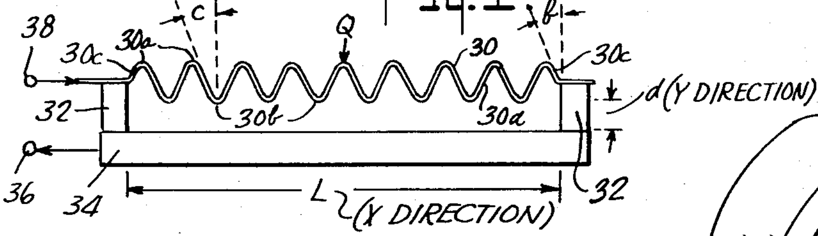
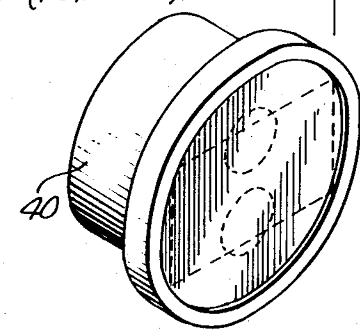


Fig.2.



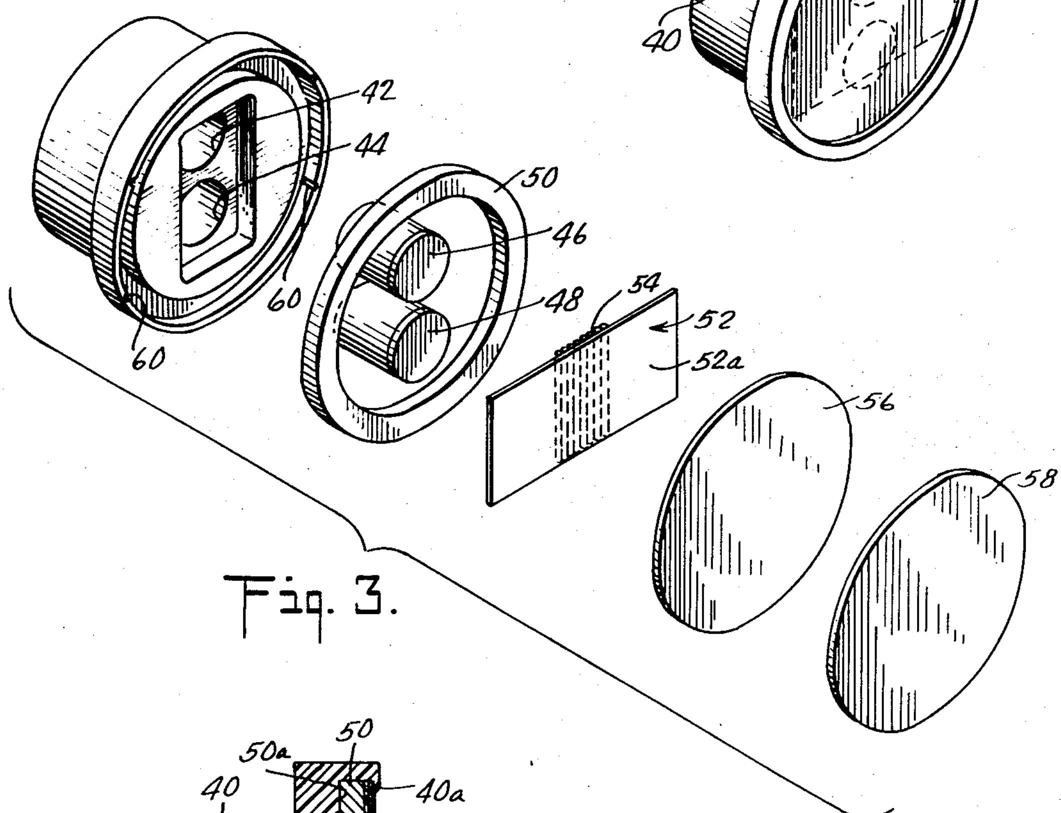
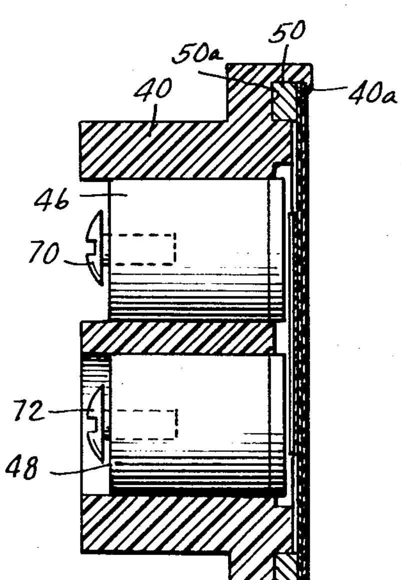


Fig. 3.



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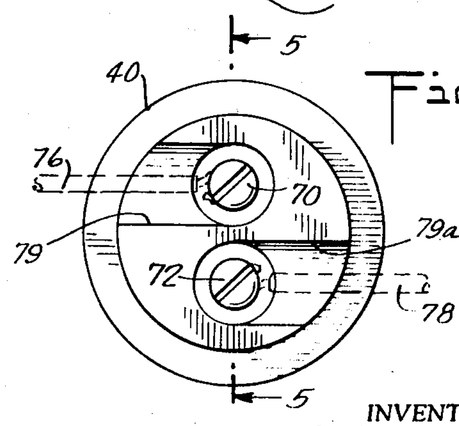

Fig. 4.

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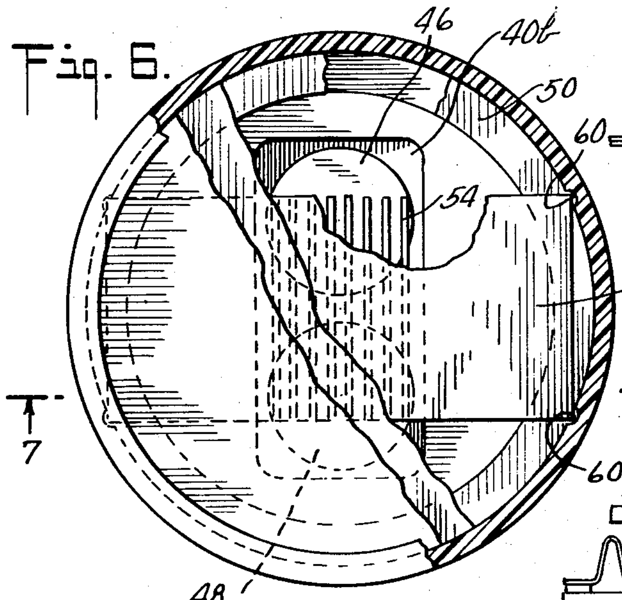
Fig. 6.



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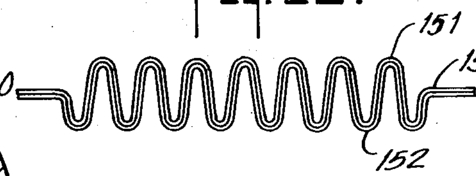

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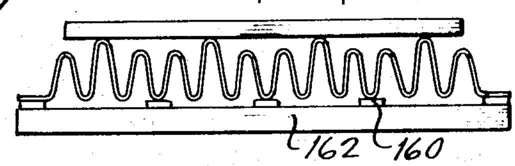

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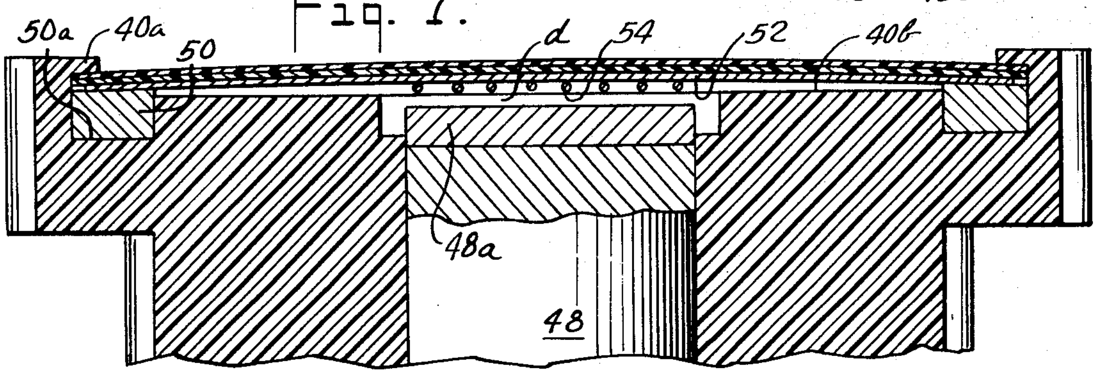

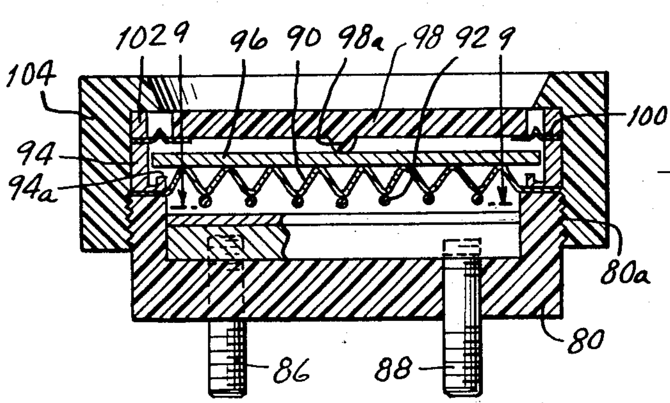

Fig. 8.

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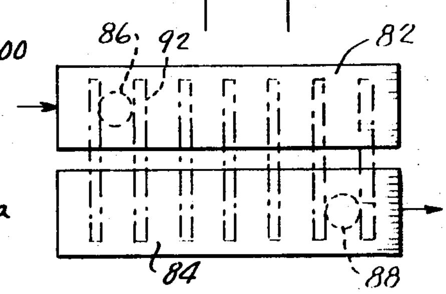

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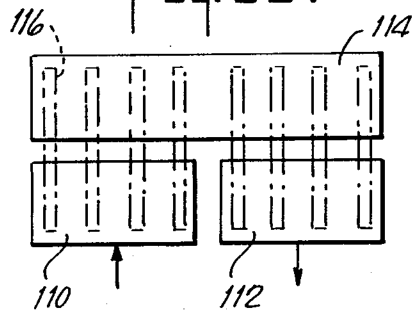

Fig. 10.

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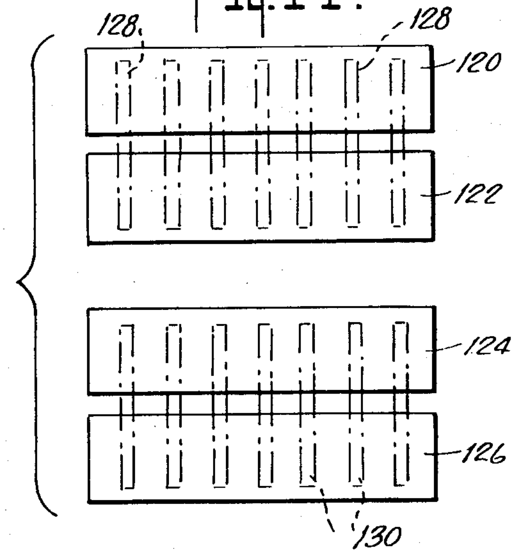

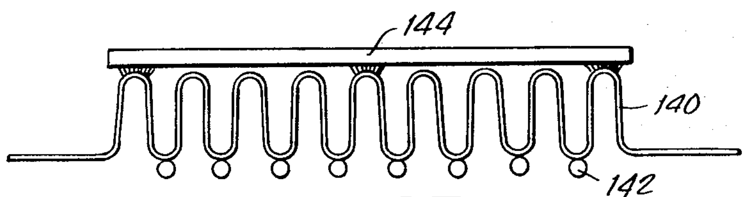

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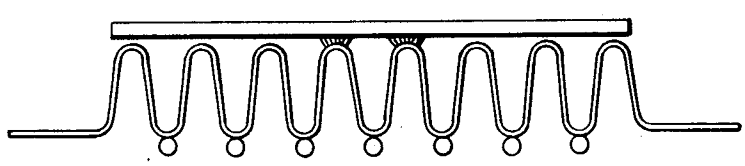

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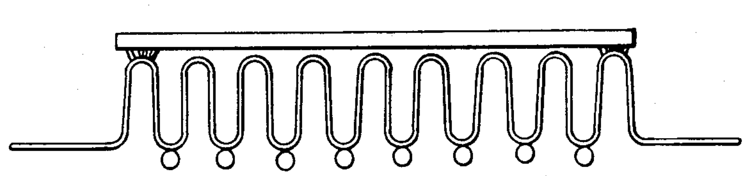

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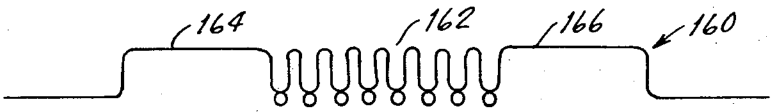

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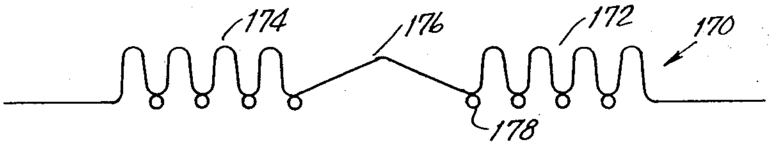

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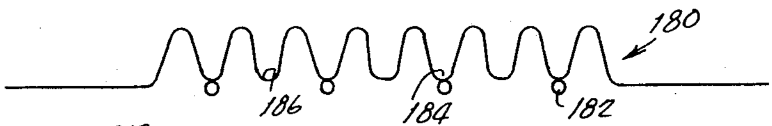

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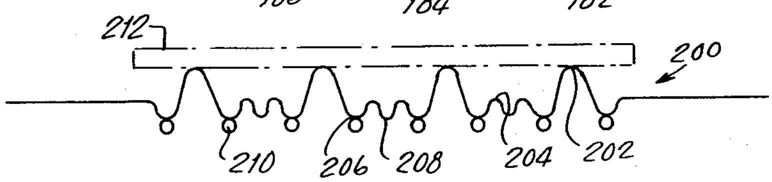

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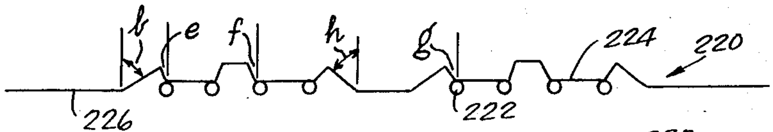

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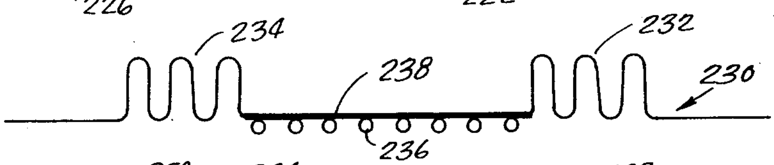

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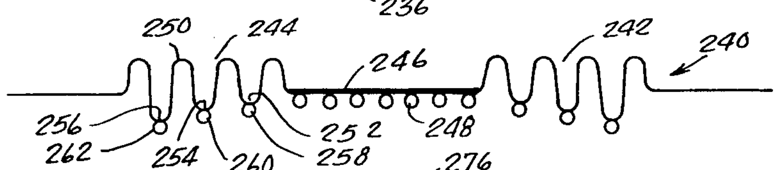

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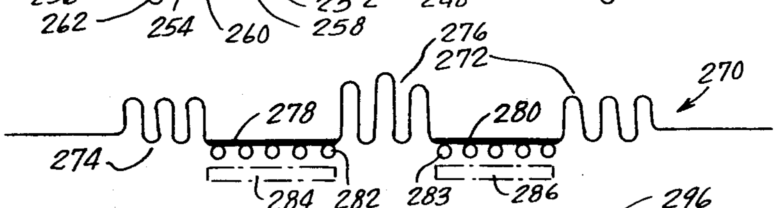

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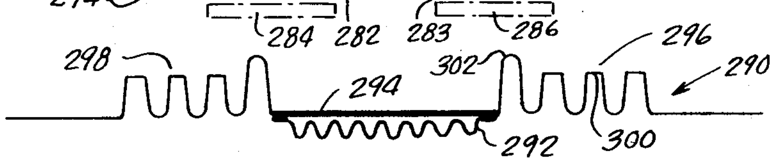

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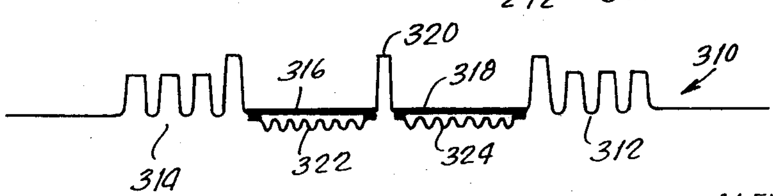

Fig. 26.

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SWITCH WITH PARTICULAR TRANSVERSE DEFLECTION CHARACTERISTICS AND MOVABLE CONTACT PLATE WITH CONTACT MAKING WIRES ATTACHED

BACKGROUND AND BRIEF DESCRIPTION OF THE INVENTION

This invention relates to a low force, low throw, touch operated 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 neighborhood of 20 or 30 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 pushbutton feeling upon actuation to the on-state, and the movable contact must be relatively thin and lightweight to provide a soft equivalent 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 buildup 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 the invention are capable of suitable operation under activation of 20 to 30 grams, maintaining reliable operation over a million or so activations, exhibition a 50 milliohm contact resistance, and embracing a voltage-amperage 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 an effective dimension L and an equivalent 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 equivalent 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 switches of the prior art.

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:

BRIEF DESCRIPTION OF THE DRAWINGS

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.

DETAILED DESCRIPTION

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 30*a* and 30*b* that lie substantially in two parallel planes. The element 30 includes inclined portions 30*c* at the axial ends thereof (each defining an angle *b* with the vertical) and inclined portions 30*d* intermediate the peaks 30*a* and 30*b* (each defining an angle *c* with the vertical). The ends of the element 30 are supported by 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 30*b* adjacent the base element 34 engage that base element.

The peaks 30*b* 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:

$$P=kx \qquad (1),$$

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:

$$Y/L\alpha(Q/KL)^{1/3} \qquad (2).$$

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

$$Q\,\alpha(K/L^2)\,y^3 \qquad (3).$$

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 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:

$$Q/ky\,\alpha(y/L)^2 \qquad (4).$$

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 *y*/*L*. It has been found that the ratio *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 30*b* and the base element 34. Because of the relatively small distance of separation *d* between the peaks and base element, an inherent 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 30*b*. The peaks 30*b* 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 30*b* 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 30*b* 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 30*b* 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 burnout 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 30*b* 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 30*b* 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 30*b* 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 conventional 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 thus 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 forced involved, i.e.

$$R\alpha\frac{1}{\sqrt{Q}}$$

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 30*b*, such as severe localized arc transfer, burnout, or the lodging of a nonconductive 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 **30***b* 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 wide 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 **30***b*. 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 activate 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 activation 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 molded in place when the housing **40** is molded. The housing **40** is advantageously of plastic. A metallic ring **50**, such as of aluminum, 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 **52***a* (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, 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 **50***a* 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 **40***a* 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 **79** and **79***a* in the housing **40**.

Typical dimensions for the switch just described might be a diameter of about 1 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 (totaling 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 aluminum 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 **40***b* of the housing. The surface **40***b* 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 **48***a* 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 AC 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 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 series of gaps between the terminal element **46** and the wires **54** and a second series of gaps between the wires **54** and the terminal element **48** which must be completed in order to complete an electrical connection between the terminal elements. An integral series-parallel multiple break action is thus provided. The series gaps are between terminal elements and wires; the parallel arrangement is achieved by the electrically parallel connected wires **54**, each of which corresponds to one of the peaks **30***b* 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 the wires **54** and the terminal element **48**. The probability of series simultaneity is greatly enhanced by the internal parallel construction utilizing peaks **30*b*** 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 **52** a 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, 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 percent 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 nonuseful 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 **80*a***. 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 **94*a*** 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 activator 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 activator plate **98** is touched. This plate communicates with the stabilizer plate through projection **98*a*** 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 element **120**, **122**, **124** and **126**. A first group of parallel positioned and 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**.

It will be noted then that the invention involves a switch which can be single pole or multipole. 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.

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.

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**.

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**.

FIGS. **17–26** show alternative forms of flexible-contact elements. In FIG. **17** element **160** includes a corrugated section **162** and noncorrugated 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 if the corrugated portion **162** were continuous from one end of the structure to the other end of the structure.

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 Vrshaped structure 176 provides for sidewise movement of wires 178 attached to the peaks of the element.

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 a s represented by the angles *e*, *f*, *g* and *h*. The intermediate angular orientations of various portions 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 midportion 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 midportion. Element 240 of FIG. 23 includes corrugated end portions 242 and 244 and a midportion 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 by 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 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 groups of wires 282 and 283. Spring action 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 portion 320. The rigid portions 316 and 318 carry 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 embodiments 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 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 equivalent 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 parallel extended 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.

We claim:

1. A low throw switch, comprising a flexible-contact element having a flexible portion and an electrical contact-making portion, said contact-making portion being comprised of a

plurality of parallel and extended contact segments, said flexible portion having an effective dimension L and an equivalent spring constant in an axial direction, a base contact spaced a distance *d* in a transverse direction from said contact segments in the fully open position of said flexible-contact element and adapted to be contacted by said contact segments upon transverse deflection of said flexible portion, the distance *d* being chosen to be less than about 0.008 inch and the distance L being chosen so that the ratio *d*/L is less than about 0.02, so that in the closed-circuit condition of said switch substantially simultaneous broad area arc distribution and electrical contacting take place between said contact segments and said base contact and enhanced deflection is obtained in the transverse direction.

2. A switch as defined in claim **1**, constituting a low force, touch-operated switch, wherein the equivalent axial spring constant is selected so that with said *d* to L relationship the thereby reduced transverse force necessary to touch actuate the switch to produce electrical contact between said contact segments and said base contact is less than about 100 grams.

3. A switch as defined in claim **2**, including two base elements adapted to be contacted by said contact segments, said contact segments thereby completing parallel electrical connections between said two base elements.

4. A switch as defined in claim **3**, in which said flexible-contact element comprises a bowed plate and a plurality of wires secured to said plate.

5. A switch as defined in claim **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. A switch as defined 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. A switch as defined in claim **1**, in which said flexible contact element comprises a plate and a plurality of wires affixed to said plate constituting said contact-making portion.

8. A switch as defined in claim **1**, in which said flexible-contact element comprises a corrugated plate.

9. A switch as defined in claim **8**, in which peaks of said corrugated plate adjacent to said base element constitute said contact segments.

10. A switch as defined in claim **8**, in which peaks of said corrugated plate adjacent to said base element include wires which constitute said contact segments.

11. A switch as defined in claim **8**, in which said corrugated plate comprises a spring material clad with a contacting material.

12. A switch as defined in claim **8**, in which said corrugated plate includes peaks lying in a plurality of planes.

13. A switch as defined in claim **12**, in which adjacent ones of said peaks define an inclined plane, so that said adjacent peaks contact said base element sequentially as said flexible-contact element is actuated.

14. A switch as defined in claim **13**, in which adjacent ones of said peaks are made of different materials.

15. A switch as defined in claim **12**, in which a plurality of said peaks adjacent to said base element are supported by insulating members resting upon said base element.

16. A switch as defined in claim **12**, including a stabilizer plate bearing against those peaks furthest away from said base.

17. A switch as defined in claim **16**, 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.

18. A switch as defined in claim **16**, including an activator member bearing against said stabilizer plate, said activator member being actuated to actuate said switch.

19. A switch as defined in claim **18**, in which said activator member comprises a plate bearing against said stabilizer plate.

20. A switch as defined in claim **19**, in which said activator member is spring mounted to a housing that supports all the elements of said switch.

21. A switch as defined in claim **1**, 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.

22. A switch as defined in claim **21**, in which said inclined portions are at edges of said flexible portion.

23. A switch as defined in claim **21**, in which said inclined portions are intermediate the edges of said flexible portion.

24. A switch as defined in claim **1**, in which said flexible-contact element comprises a plate which is corrugated at edges thereof for flexiblity and which includes a rigid section carrying another corrugated plate of which peaks thereof constitute said contact segments.

25. A switch as defined in claim **1**, wherein said contact segments extend over a distance in the axial direction only so far that substantially all of said contact segments are brought into electrical contact with said base element upon touch actuation by the finger of a user.

26. A switch as defined in claim **1**, 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 each gap in an electrical parallel sense in the actuated state of the switch.

27. A switch as defined in claim **1**, in which said flexible-contact element comprises a plate, and including means providing a support surface for the edges of said plate.

28. A contact element for a switch, comprising a flexible conductive plate of thickness such that the plate is actuable upon finger contact when the plate is mounted for such finger contact, and a plurality of conductive wires curved in section and conductively affixed to the plate to exhibit pronounced wiping and rolling action upon touch activation along with enhanced impact pressures due to the curvature of the wires.

29. A contact element for a switch as defined in claim **28**, in which said plate is bowed so that it is concave.

30. A contact element for a switch as defined in claim **29**, in which said concave plate includes no compound curves on said surface containing said wires.

31. A contact element for a switch as defined in claim **28**, in which said plate is substantially planar.

32. A contact element for a switch as defined in claim **28**, in which said plate is of brass.

33. A contact element for a switch as defined in claim **28**, in which said wires are of silver cadmium oxide.

34. A contact element for a switch as defined in claim **28**, in which said wires are all positioned parallel with respect to each other, each wire constituting a straight line segment.

35. A contact element for a switch as defined in claim **34**, in which said wires are between about 0.009 and 0.017 inch in diameter and are spaced no more than about 0.050 inch from each other, said flexible conductive plate is no more than about 0.002 inch thick, and said wires extend over a distance of less than about 1 inch in an axial direction transverse to the direction of the wires.

36. A switch incorporating a contact element as defined in claim **34**, including a fixed base element adjacent said contact element and which is contacted by said wires in the closed-circuit condition of said switch, said switch being designed for touch operation, in which said wires are spaced no more than about 0.008 inch on the average from said base element in the fully open position of said contact element, and said wires extend over a distance of less than about one inch in an axial direction transverse to the direction of the wires.

37. A switch as defined in claim **36**, in which said plate is of brass, and said wires are of silver cadmium oxide.

38. A switch incorporating a contact element as defined in claim **28**, and including a fixed base element adjacent the contact element which is contacted by said wires in the closed-circuit condition of said switch.

39. A switch as defined in claim **38**, in which the flexibility of the conductive plate is such that a contact force of less than about 100 grams is required to actuate the switch.

40. A switch as defined in claim 38, in which said base element includes a single piece of material conductive throughout its entirety.

41. A switch incorporating a contact element as defined in claim 28, including two fixed base elements adjacent said contact element and which are contacted by said wires in the closed-circuit condition of said switch thereby to complete parallel electrical connections between said two base elements.

42. A switch, comprising a first electrically conductive contact element, and a second contact element movable into and out of electrical contact with the first element, the second contact element comprising flexible plate means having a smooth outer surface and an inner surface facing the first contact element and which is actuable upon finger contact with the outer surface, and a plurality of conductive wires curved in section and affixed to the inner surface of said plate means and which are in electrical contact with the first contact element in the closed-circuit condition of said switch, a change in the electrical condition of said switch being effected upon actuation of said plate means and concomitant movement of said conductive wires with respect to said first contact element, said second contact element exhibiting pronounced wiping and rolling action upon touch activation along with enhanced impact pressures due to the curvature of the wires.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,602,677 Dated August 31, 1971

Inventor(s) Alexander M. Adelson and Jerome Swartz

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, Line 72, after "5" insert --%--;

Column 9, Line 62, "by" should be --be--;

Column 9, Line 69, before "278 and 280." insert --portion 276 in the central region of the element, and intermediate rigid portions--;

Column 12 (Claim 24) Line 11, after "section" insert --in an intermediate portion thereof, said rigid section--.

Signed and sealed this 23rd day of January 1973.

(SEAL)
Attest:

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ROBERT GOTTSCHALK
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