April 23, 1963 R. W. BETHKE 3,087,038

ELECTRIC CURRENT INTERCHANGE CONTACT

Filed Oct. 19, 1959

3 Sheets-Sheet 1

Fig. 1

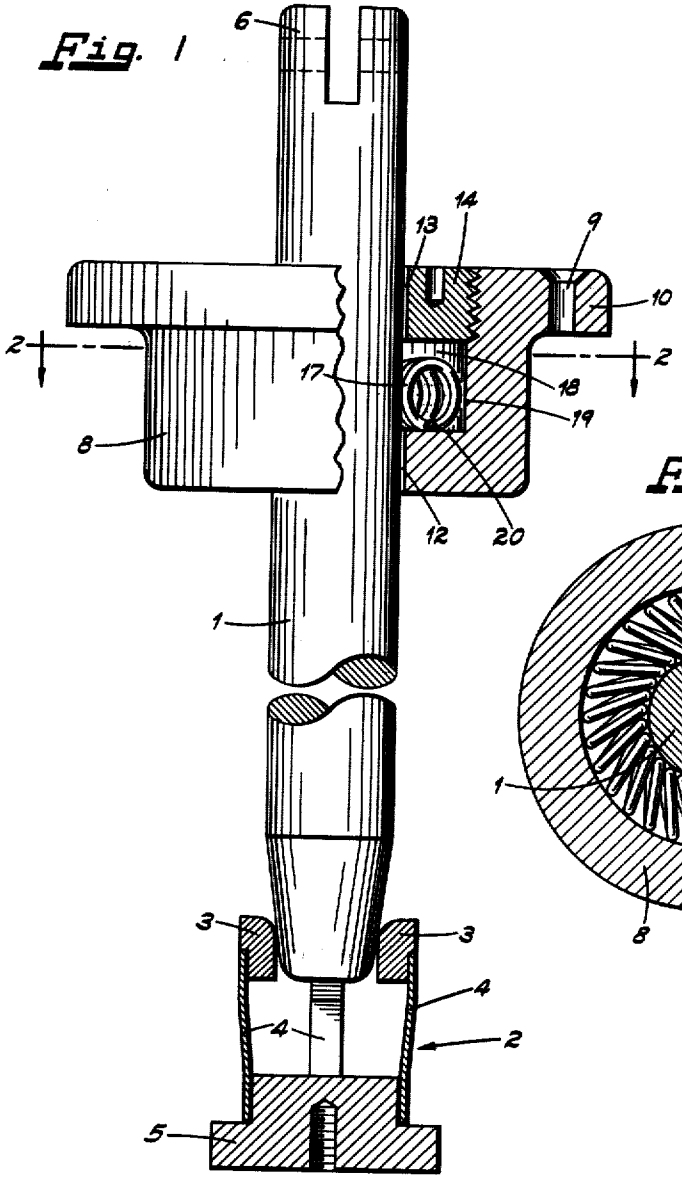
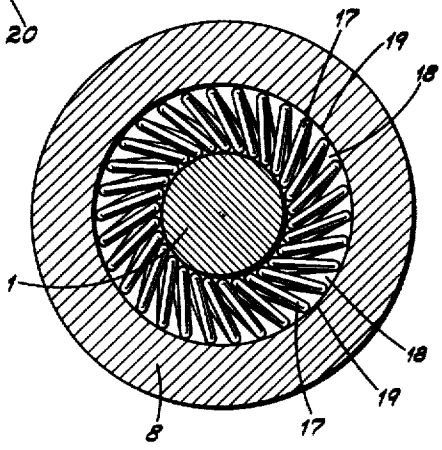



Fig. 2




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Fig. 3

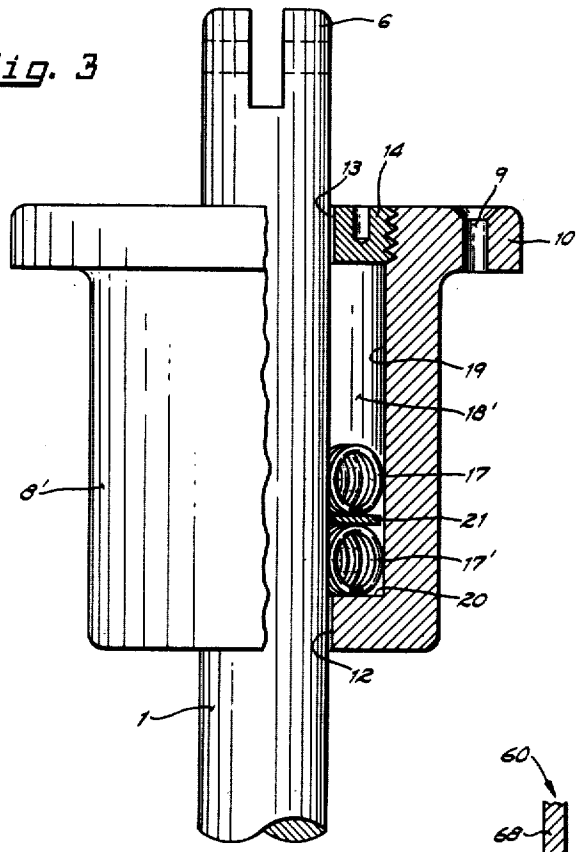
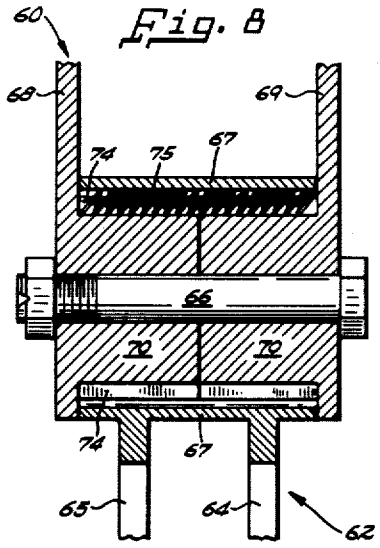



Fig. 8



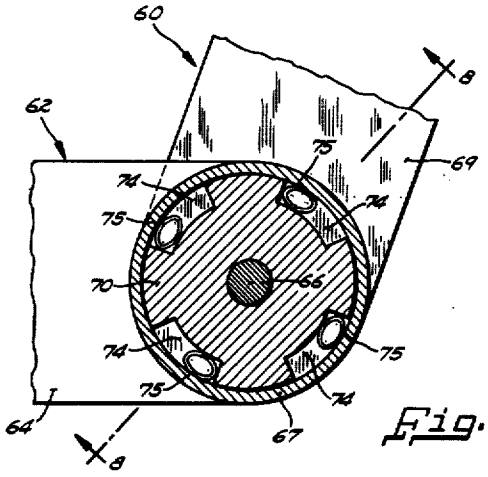




Fig. 7

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ELECTRIC CURRENT INTERCHANGE CONTACT

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Fig. 4

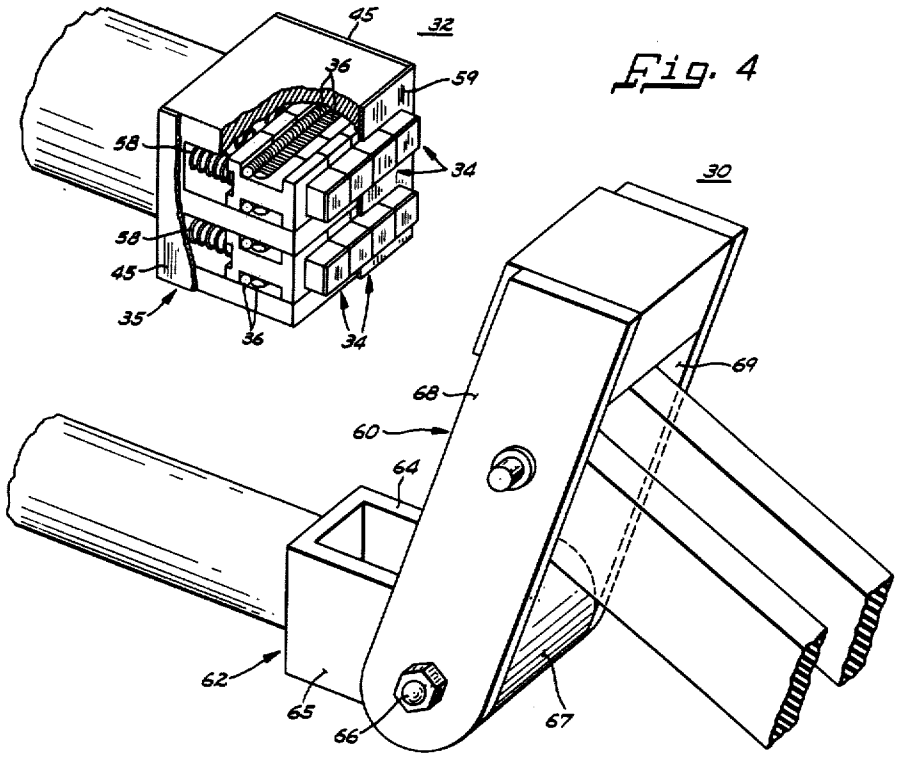



Fig. 5

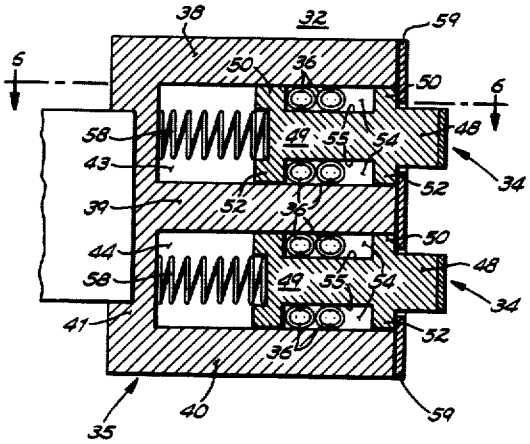
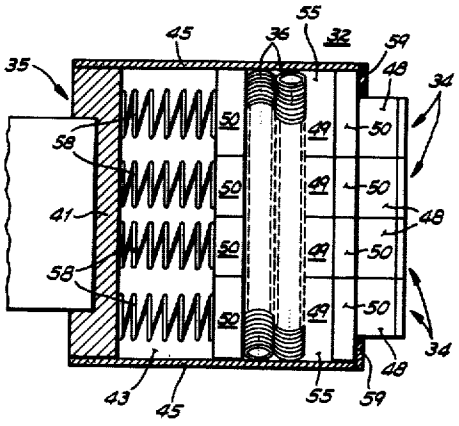



Fig. 6




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United States Patent Office 3,087,038 Patented Apr. 23, 1963



3,087,038

# ELECTRIC CURRENT INTERCHANGE CONTACT

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Filed Oct. 19, 1959, Ser. No. 848,888
19 Claims. (Cl. 200—166)

This invention relates to electric contacts and more particularly to a means for transferring current of large magnitude between conductive components which coact slidably or rotatably in electrical apparatus.

This is a continuation-in-part of copending application Ser. No. 505,293, filed May 2, 1955, and which is now abandoned.

In circuit breakers, switches and other electrical devices, it is often necessary that current be conducted between components which are mechanically related but free to exercise a predetermined swinging or sliding movement with respect to each other. For example, in a circuit breaker an elongated rod like contact may be arranged for sliding into and out of electrical engagement with a fixed contact so that current may be transferred during the conductive period from the sliding contact to its guiding member. In a circuit interrupter it is common to transfer current from a swinging arm to an arm support through a poorly conductive hinged joint, and also between a stationary contact block and contact fingers slidably received therein. These are but a few of the instances where it will be evident to those versed in the art that a high resistance junction may develop between movable parts which would manifest itself in the form of heat and excessive voltage drop across the apparatus and which results in rapid wear

The prior art demonstrates a variety of means for mitigating the aforementioned affects such as, by paralleling the high resistance junction between movable parts by means of flexible shunts, cam and follower arrangements, and direct acting wiping contacts. Moreover, in the hinge joints various means of achieving high pressure contact have been used: for example, hinged parts may be biased into high pressure relation in an effort to minimize contact resistance between them.

Despite the abundance of known current interchange means, none of these devices are fully satisfactory because they frequently deteriorate after prolonged use, and because they are costly, intricate and difficult to incorporate where space limitations are an important factor.

A general object of this invention is to overcome the above indicated defects in the prior art by providing a novel and efficient means for transferring current through rotatable and slidable joints between movable components of electrical apparatus.

A principal object of the invention is to provide a contact which offers only infinitesimal mechanical rolling friction between components.

Other more specific objects are: to provide a current transfer contact which is simple in form and easily manufactured and installed; to provide a contact which is endowed with inherent ability to compensate for wear, if any; to provide a contact which may be conveniently ganged or stacked for accommodation of large magnitude currents; and, to provide a contact which is free floating and self-adjusting thereby eliminating sizing or binding of the parts.

Another important object is to provide a current transfer contact which increases its bearing pressure through self-generating electromagnetic effects, when subjected to inordinate current flow.

These and other objects of the invention will become apparent from the detailed description of the invention taken in view of the accompanying drawings in which:

FIG. 1 is an elevational view, partly in section, of a



circuit breaker contact assembly incorporating one embodiment of the instant invention;

FIG. 2 is a sectional view, taken along lines 2—2 of FIG. 1;

FIG. 3 is an elevational view, partly in section, of an alternative form of the invention;

FIG. 4 illustrates how other embodiments of the instant invention may be incorporated in a circuit interrupter;

FIG. 5 is a sectional view of a circuit breaker contact embodying the instant invention;

FIG. 6 is a view taken along lines 6—6 of FIG. 5;

FIG. 7 illustrates another application of the rolling current interchange spring according to the instant invention; and

FIG. 8 is a view taken along lines 9—9 of FIG. 7.

In general terms, the invention comprises a current interchange means where current is transferred between relatively movable members through the agency of a helically wound spring. The springs are disposed in a groove in one of the members whose dimension in the direction of relative movement is substantially greater than the helical diameter of the springs. During relative movement between the conductive members, the spring is caused to roll in said groove so that only rolling friction is encountered at the current interchange joint. As a result, the amount of force necessary to move the relatively movable members is substantially reduced and the amount of wear experienced is negligible. In a more specific form of the invention the depth of these grooves is less than the helical diameter of the springs so that all convolutions thereof are inclined, whereby contact bearing pressure is obtained from their tendency to straighten out. For higher values of current a plurality of springs may be utilized having their convolutions inclined in opposite directions relative to springs adjacent thereto to prevent intermingling of their convolutions. In order to achieve rolling friction during the entire period of relative movement, the width of the groove is made equal to the sum of the diameters of all the springs utilized plus one half the distance between the limits of said relative movement.

Referring to the drawings in greater detail, FIG. 1 shows an elongated rod-like contact 1, of a suitable conducting material such as copper, arranged for executing rapid movement into and out of electrical engagement with a stationary contact 2. Although means for effecting rapid longitudinal travel of rod 1 are not shown, it may be assumed that any well known driving means is attached to rod 1 at its upper end 6 for this purpose. In practice, suitable arc extinguishing means would be provided in the vicinity of contact 2 for confining the arc formed thereabout during a circuit interrupting operation but this structure is omitted for the sake of brevity.

In connection with FIG. 1, it may be assumed that the objective is to transfer current from movable rod 1 to a stationary terminal assembly 8 to which a line wire (not shown) is attached, the transfer being effected through the agency of a current interchange spring 17. In closed circuit position, rod 1 is received by the stationary contact 2 which may take any well known form but is shown here comprising a conductive base 5 for attachment to a line wire (not shown). Flat upstanding resilient springs 4 are mounted on base 5 and are provided with copper tungsten arcing tips 3. Conductive terminal casing 8 may be securely mounted in a circuit breaker or other electrical apparatus through the agency of bolt holes 9 formed in an integral supporting flange 10.

Additional guidance for rod 1 is obtained by passing it through a clearance hole 12 in the bottom of terminal housing 8 and a bushing 14 shown threaded into housing 8 and provided with an aperture 13. It is not intended

that appreciable current be transferred from rod **1** to the inner walls of apertures **12** and **13**, their fit with rod **1** being such as to allow free rotation or sliding thereof. While rod **1** is shown to have a circular cross section it will be understood that it may also be polygonal in cross section without departing from the terms of the invention.

According to the invention current transfer is accomplished by means of a current pick up coil spring **17** which resides in a circular channel or groove **18**, formed in terminal **8** so that the spring wraps around and bears against rod **1** like a closely surrounding toroid, the outer diameter of which is in current exchanging contact relation with the peripheral walls **19** of channel **18** and whose inner periphery bears on rod **1**.

By reference to FIG. 2 it will be apparent that each successive convolution of spring **17** is inclined at an angle with respect to the radius of rod **1** and its own helical axis thus accounting for the fact that the spring fits into a channel **18** which has a smaller width than the diameter of the individual spring convolutions. When the spring is disposed in this position, contact pressure on rod **1** and channel wall **19** is derived from internal stress which tends to right the convolutions to an untilted position so that each convolution has the effect of one force member interposed between two fixed points. Because spring **17** is inclined, this force is vertically divisible into two components with respect to the surface against which it bears, the first being normal to the periphery of rod **1** and the second being tangential thereto. This is due in part to the normal contact force varying in magnitude substantially as the cosine of the inclined angle when that angle has its vertex where the outer periphery of the convolution makes point contact with wall **19** and is measured from the face of the convolution to a radius extending to the same point from the center of rod **1**. A tilt angle from 30 to 45 degrees has been found to yield the best results. This suggests why the width of channel **18** is not extremely critical in the invention, since the stresses set up in the spring **17** are not linearly related to the strain created by the channel walls acting thereon; rather, they vary nonlinearly as does the sine function. Hence, a few thousandths of an inch of variation in channel width produces only a fractional difference in the bearing pressure exerted by spring **17**.

It will be understood by those skilled in the art that the proportions of spring **17** are determined by the magnitude of the current to be transferred and the type of material utilized. For proper functioning of the tilted spring transfer contact **17**, the circumference of rod **1** should be greater than the length of spring **17** when it is closely wound and extended in a straight axial direction to prevent interference between adjacent convolutions. This insures that spring **17** will fit into channel **18** when the former is inserted with its convolutions tilted.

After spring **17** is wound, it is preferable, although not absolutely necessary, that its free ends by joined to form a circular or toroidal unitary spring having an inside opening somewhat smaller than the diameter of rod **1**. This may be accomplished by directly welding the ends thereof, by joining the ends in a sleeve and staking them together, or by merely intertwining the last few turns of each end. Spring **17** may also be wound with the convolutions having a preset angular inclination which facilitates installation and controls its internal stresses.

It should be noted that the axial width of channel **18** in FIG. 1, exceeds the helical diameter of the spring **17**. The longitudinal freeplay thus created allows spring **17** to roll in the axial direction of rod **1**, when the rod is caused to move axially, until the spring stops against bushing **14** or channel bottom **20**, depending upon the direction of movement. Thereafter, as the stroke of rod **1** continues, it merely slides within the spring **17** toroid. Rolling of the spring current exchange means is akin to mounting the rod **1** on ball bearing guides whereby static friction is reduced and a correspondingly rapid acceleration of the moving contact **1** is facilitated.



It should be understood that the phrases "helical diameter" and "diameter of the spring convolutions" or "diameter of the convolutions" or "diameter of the spring," wherever used in this specification or the appended claims, means the outer diameter of the spring when wound as an untilted helix. It should be further understood that the "width" of the groove, means its dimension parallel to the direction of relative movement while its "depth," means its dimension perpendicular to said direction.

In an alternate form of the invention shown in FIG. 3 the width of channel **18'** is substantially equal to one-half the stroke of rod **1** plus the helical diameters of springs **17** and **17'**. This allows current interchange springs **17** and **17'** to roll during the entire stroke of rod **1** because a body rolling on a cylinder or ball travels approximately twice as far as the cylinder itself. As a result, not only is very little starting friction encountered, but the friction remains at a small value during the entire contact opening and closing operation. The second current interchange spring **17'** is shown in FIG. 3 to illustrate that for large current applications a plurality of springs, may be used. If the springs **17** and **17'** are inclined in the same direction an annular spacer member **21**, should be utilized. Spacer **21** is not necessary, however, if the springs are inclined in opposite directions to prevent intermingling of their convolutions. When additional springs are used the width of the channel or cavity **18'** should be increased by the diameter of each such additional spring so that they will be free to roll through the entire stroke of rod **1**. It will be appreciated that the current interchange means shown in FIGS. 1 and 3 may also be utilized to transfer current between reciprocating members.

In circuit breakers utilizing butt type contacts as shown in FIG. 4, it has been determined that in order to prevent the contacts from blowing open and/or subsequently welding, one contact finger per 15 to 20 thousand peak instantaneous amperes is required. The exchange of current between the moving arm **30** and the stationary contact **32** is further complicated by the necessity for over-travel required to allow a latch or toggle to move over its set position and relax back against the stop so that the movable contact **30** may be held in closed position. In addition, slight changes in the adjustment of the operating mechanism should not affect the contact pressure between the fixed and movable contact members.

The contact mechanism shown in FIGS. 4–6 satisfies each of these requirements. In general terms the contact structure includes a plurality of contact fingers **34** reciprocably mounted in a contact block **35**. Current is transferred between the contact fingers **34** and contact block **35** by means of current interchange springs disposed therebetween and lying with their helical axes substantially perpendicular to a plane containing the direction of movement of said contact fingers.

More specifically, contact block **35** includes three spaced apart plate-like sections **38**, **39** and **40** which are joined by an end portion **41** and which define, with end plates **45**, a pair of parallel rectangular slots or cavities **43** and **44**.

Each of the contact fingers **34** includes a head portion **48** and a body portion **49** having a substantially H-shaped cross section. The lateral surfaces of the upper and lower arms **50** and **52** respectively, of each body portion **49**, slidably engage the upper and lower walls of their associated cavities **43** and **44**. The space between these upper and lower arms provides a spring channel **54** for receiving current interchange springs **36**. As can be seen in FIGS. 4 and 5 the individual spring channels **54** of each contact finger **34** are in substantial registry so that each current interchange spring may overlay all of the contact fingers.

As seen in FIG. 5, the depth of each of the spring channels **54** is less than the helical diameter of the interchange springs **36** so that each spring is obliged to lay

over at an angle dictated by the depth of said channel. The tendency of the spring to assume its unstressed shape provides contact pressure between the walls of cavities **43** and **44** and the inner surface **55** of spring channels **54**. If a plurality of springs are employed in any spring cavity, adjacent springs are laid over in opposite directions, as shown in FIG. 6, to prevent mingling of the individual convolutions.

A biasing spring **58** is provided to urge each of the contact fingers **34** against stop plate members **59**, disposed at the front of the contact block **35**, and each of which overlaps slightly the openings of the contact finger cavities. Springs **58** provide contact pressure between the contact fingers **34** and the movable contact **30** and also allow for the over-travel of said movable contact mentioned above. As a result of this over-travel, the contact fingers **34** are forced further into their respective contact finger cavities against the biasing force of their individual contact pressure springs **58**. During this movement current interchange springs **36** provide a rolling connection between contact fingers **34** and plate portions **38**, **39** and **40** of contact block **35**. As a result only a small frictional force is encountered by movable contact **30** so that rapid closing of the contacts is not inhibited and the wear on the movable parts of fixed contact **32** is relatively small. In addition, this novel current interchange means allows each of the contact fingers **34** to move individually so that a good contact can be achieved between each of the contact fingers and the movable contact **30**. Here again, the width of each of the spring channels **54** is equal to approximately one-half the amount of contact finger travel plus the sum of helical diameters of each contact spring utilized so that only rolling friction is encountered.

FIGS. 7 and 8 illustrate how the rolling spring contact principle can be applied to relatively rotatable members. By way of example, the embodiment of FIGS. 6 and 7 will be discussed in relation to the transfer of current between switch arm **60** of movable contact **30** and the stationary conductive member **62** upon which it is rotatably mounted by means of a pivot pin **63**. Conductive member **62** is substantially U-shaped with its legs **64** and **65** joined at one end by cross piece **66** and at their other by a cylindrical conductive sleeve **67**. Similarly, each of the arms **68** and **69** of rotatable contact **30** is joined at its pivotal ends by cylindrical conductive member **70** which is slidably received within sleeve **67**. A plurality of spaced apart substantially parallel channels **74** are formed in the surface of cylindrical member **70** for receiving current interchange springs **75**. Here again, the depth of recesses **74** is less than the diameter of springs **75** so that the convolutions thereof are forced to lay over whereby contact pressure with cylinder **70** and sleeve **66** is provided. The arcuate width of each of the grooves **74** is approximately equal to one half of the arc intercepted by the rotational angle of switch arm **60** plus the diameter of springs **75** so that only a rolling friction is encountered as switch arm **60** oscillates between open and closed position.

The number of grooves **74** and springs **75** employed in cylindrical member **70** is determined by the magnitude of the current to be transferred. A plurality of springs **75**, each having an angle of inclination different from adjacent springs, may also be used in each groove where large currents are involved.

For purposes of illustration, each of the embodiments shows the spring receiving groove or channel formed in a particular one of the members, but those skilled in the art will understand that it also may be formed in either member or that a portion may be formed in both members.

Also, while each of the embodiments has been discussed with respect to particular types of interchange structure, these are merely intended as examples. Accordingly, it is intended to cover in the appended claims, the rolling spring principle of current interchange in all types of applications.



I claim:

1. In electrical apparatus, current interchange means comprising a pair of relatively movable conductive members, means associated with said members for providing an elongate channel having its open side disposed toward one of said members, a helical spring contact disposed in said channel, the normal distance between said members and across said channel being substantially uniform, said distance being less than the outside helical diameter of the convolutions of said spring to incline said convolutions at an angle relative to the helical axis of said spring so that the resiliency of said spring normally holds said convolutions in firm electrical contact with said members, the width of said channel in the direction of relative movement exceeding the diameter of said convolutions so that said spring rolls during said movement whereby rolling friction is encountered between said members and said spring contact.

2. In electrical apparatus, current interchange means comprising a pair of relatively movable conductive members, means associated with one of said members to provide an elongate channel having an open side disposed toward the other member, a helical spring contact disposed in said channel, said channel and said spring being so arranged that a plane containing the helical axis of said spring is perpendicular to the direction of relative movement, the normal distance between said members and across said channel being substantially uniform and less than the outside helical diameter of the convolutions of said spring so that the planes of said convolutions are inclined at an angle relative to its helical axis, the resiliency of said spring normally holding substantially all of said convolutions in firm electrical contact with said members, the dimension of said channel in the direction of relative movement exceeding the diameter of said convolutions so that said spring rolls during said relative movement whereby rolling friction is encountered between said members and said spring contact.

3. In electrical apparatus, current interchange means comprising a pair of conductive members, one of said conductive members being relatively fixed and the other being movable between first and second positions, means integrally formed with one of said members to provide an elongate channel having its open side disposed adjacent the other member, helical spring contacts disposed in said channel, the depth of said channel being substantially uniform and less than the outside helical diameter of said springs so that the convolutions thereof have their planes inclined at an angle relative to its helical axis, whereby the resiliency of said springs normally holds said convolutions in uniformly advancing spiral relation with each other and maintains said convolutions in firm electrical contact with said members, the width of said channel in the direction of movement of said movable member being approximately equal to the diameter of said convolutions plus one-half the distance between said first and second positions so that said springs roll during the entire movement of said movable member between their first and second positions whereby rolling friction is encountered between said members and said spring contact.

4. In electrical apparatus, current interchange means comprising a pair of conductive members, one of said conductive members being relatively fixed and the other being movable between first and second positions, elongate channel means provided in one of said members and having its open side disposed adjacent the other, a helical spring contact disposed in said channel means, the depth of said channel means being substantially uniform and less than the helical diameter of said spring so that the convolutions thereof have their planes inclined at an angle relative to its circumferential axis, whereby the resiliency of said spring normally holds said convolutions

in uniformly advancing spiral relation with each other and maintains said convolutions in firm frictional contact with said members, the width of said channel in the direction of movement of said movable member being approximately equal to the diameter of said convolutions plus one-half the distance between said first and second positions so that said spring rolls during the entire movement of said movable member between its first and second positions whereby rolling friction is encountered between said members and said spring contact.

5. In electrical apparatus, current interchange means comprising a substantially cylindrical internal conductive member and a substantially cylindrical external conductive member surrounding a part of said internal member in concentric relation, means associated with at least one of said members for providing an elongate channel having an open side disposed toward the other member, a helical spring contact disposed in said channel, the normal distance between said members and across said channel being substantially uniform, said distance being less than the outside helical diameter of the convolutions of said spring to incline said convolutions at an angle relative to the helical axis of said spring so that the resiliency of said spring normally holds said convolutions in firm electrical contact with said members, the dimension of said channel in the direction of relative movement exceeding the diameter of said convolutions so that said spring rolls during said movement whereby rolling friction is encountered between said members and said spring.

6. In electrical apparatus, current interchange means comprising a substantially cylindrical internal conductive member and a substantially cylindrical external conductive member surrounding a part of said internal member in concentric relation, means associated with said members to provide an elongate channel having an open side disposed toward the other member, a helical spring contact disposed in said channel, said channel and said spring being so arranged that a plane containing the helical axis of said spring is perpendicular to the direction of relative movement, the normal distance between said members and across said channel being substantially uniform and less than the outside helical diameter of the convolutions of said spring so that the planes of said convolutions are inclined in an angle relative to its helical axis, the resiliency of said spring normally holding substantially all of said convolutions in firm electrical contact with said members, the dimension of said channel in the direction of relative movement of said members being approximately equal to the helical diameter of said spring plus one-half the distance between said first and second positions so that said spring rolls during the relative movement of said members whereby rolling friction is encountered between said members and said spring.

7. In electrical apparatus, current interchange means comprising a stationary conductive member and a relatively movable conductive member adjacent said stationary member, means providing an elongate channel in one of said members and having its open side disposed toward the other, a helical spring contact disposed in said channel and having a substantially linear helical axis, said channel and said spring being so arranged that a plane containing the helical axis of spring is substantially perpendicular to the direction of said relative movement, the depth of said channel being substantially uniform and less than the outside diameter of said spring so that the convolutions thereof have their planes inclined at an angle relative to its helical axis, the resiliency of said spring normally holding said convolutions in firm frictional contact with said members, the width of said channel in the direction of relative movement exceeding the diameter of said convolutions so that said spring rolls during the relative movement of said members whereby rolling friction is encountered between said members and spring contact.

8. In electrical apparatus, current interchange means comprising a stationary conductive member and a relatively movable conductive member adjacent said stationary member and operable between first and second positions, means providing an elongate channel in one of said members and having its open side disposed toward the other, a helical spring contact disposed in said channel, the helical axis of said spring being substantially linear, said channel and said spring being so arranged that a plane containing said helical axis is perpendicular to the direction of said relative movement, the depth of said channel being substantially uniform and less than the helical diameter of said spring so that the convolutions thereof have their planes inclined at an angle relative to its circumferential axis, whereby the resiliency of said spring normally holds said convolutions in uniformly advancing spiral relation with each other and maintains said convolutions in firm frictional contact with said members, the width of said channel in the direction of relative movement of said members being approximately equal to the helical diameter of said spring plus one-half the distance between said first and second positions, so that said spring rolls during the relative movement of said members whereby rolling friction is encountered between said members and spring contact.

9. In electrical apparatus, current interchange means comprising a substantially cylindrical internal conductive member and a substantially cylindrical external conductive member surrounding a part of said internal member in concentric relation, one of said members being axially movable relative to the other, means associated with said members to provide an elongate channel having an open side disposed toward one of said members, a helically wound spring contact disposed in said channel, the helical axis of said spring lying in a plane substantially perpendicular to the direction of said axial movement, the normal distance between said members and across said channel being substantially uniform, said distance being less than the outside helical diameter of the convolutions of said spring to incline said convolutions at an angle relative to the helical axis of said spring so that the resiliency of said spring normally holds said convolutions in firm electrical contact with said members, the dimension of said channel in the direction of relative movement exceeding the diameter of said convolutions so that said spring rolls during said movement whereby rolling friction is encountered between said members and said spring contact.

10. In electrical apparatus, current interchange means comprising a substantially cylindrical internal conductive member and a substantially cylindrical external conductive member surrounding a part of said internal member in concentric relation, one of said members being axially movable relative to the other and between first and second positions, means associated with at least one of said members for providing a substantially annular channel having an opening toward the other member, the axis of said channel lying in a plane substantially perpendicular to the direction of said axial movement, a helically wound spring contact disposed in said channel, the depth of said channel being substantially uniform and less than the helical diameter of said spring so that the convolutions thereof have their planes inclined at an angle relative to its helical axis whereby the resiliency of said spring normally holds said convolutions in uniformly advancing spiral relation with each other and maintains said convolutions in firm frictional contact with said members, the width of said channel in the direction of relative movement of said members being approximately equal to the diameter of said convolutions in said direction plus one-half the distance between said first and second positions so that said spring rolls during the entire portion of said relative movement whereby rolling friction is encountered between said members and said spring contact.

11. In electrical apparatus, current interchange means comprising a substantially cylindrical internal conductive member and a substantially cylindrical external conductive member surrounding a part of said internal element in

concentric relation, one of said members being axially movable relative to the other and between first and second positions, at least one of said members having means to provide a substantially annular channel opening toward the other, the axis of said channel lying in a plane substantially perpendicular to the direction of said axial movement, a plurality of helically wound spring contacts disposed in said channel with their helical axes in substantially parallel relation, the normal distance between said members and across said channel being substantially uniform and less than the outside diameter of the convolutions of each of said springs, so that said convolutions have their planes inclined at an angle relative to their helical axes, the resiliency of said springs normally holding said convolutions in uniformly advancing spiral relation with each other and maintaining said convolutions in firm frictional contact with said members, each of said springs being inclined in an opposite direction relative to each spring adjacent thereto to prevent intermingling of their convolutions, the dimension of said channel in the direction of relative movement of said members being approximately equal to the sum of the diameters of the convolutions of all of said springs in said direction plus one-half the distance between said first and second positions so that said springs roll during the relative movement of said members whereby rolling friction is encountered between said members and said spring contact.

12. In electrical apparatus, current interchange means including a substantially cylindrical internal conductive member and a substantially cylindrical external conductive member surrounding a part of said internal member in concentric relation, one of said members being rotatable relative to the other, means associated with at least one of said members to provide a channel having an open side adjacent the other member, the axis of said channel being substantially parallel to the axis of said elements, a helically wound spring contact disposed in said channel, the distance between said members normal to the direction of relative movement and across said channel being substantially uniform, said distance being less than the outside helical diameter of the convolutions of said spring to incline said convolutions at an angle relative to the helical axis so that the resiliency of said spring normally holds said convolutions in firm electrical contact with said members, the dimension of said channel in the direction of rotation exceeding the outside diameter of said convolutions so that the spring may roll during said rotational movement whereby rolling friction is encountered between said members and said spring contact.

13. In electrical apparatus, current interchange means having a substantially cylindrical internal conductive member and a substantially cylindrical external conductive member surrounding a part of said internal element in concentric relation, one of said members being rotatable relative to the other between first and second angular positions, at least one of said members having a linear channel associated therewith having its open side disposed adjacent the other member, the axis of said channel being substantially parallel to the axis of said members, a helically wound spring contact disposed in said channel, the normal distance between said members and across said channel being substantially uniform and less than the helical diameter of said spring so that the convolutions thereof have their planes inclined at an angle relative to its helical axis whereby the resiliency of said spring normally holds said convolutions in uniformly advancing spiral relation with each other and maintains said convolutions in firm frictional contact with said members, the width of said channel in the direction of rotation being approximately equal to the diameter of said convolutions plus one-half the arcuate distance between said first and second angular positions, so that the spring rolls during the entire portion of said rotational movement whereby rolling friction is encountered between said members and said spring contact.

14. In electrical apparatus a current interchange means having a substantially cylindrical internal conductive member and a substantially cylindrical external conductive member surrounding a part of said internal member in concentric relation, one of said members being rotatable relative to the other, at least one of said members having a plurality of groove means formed therein whose open side is disposed adjacent the other member, the axis of each of said groove means being substantially parallel to the axis of said members and to each other, a helically wound spring contact disposed in each of said groove means with their helical axes in substantially parallel relation, each of said grooves having a substantially uniform depth, said depth being less than the outside helical diameter of the convolutions of said spring to incline said convolutions at an angle relative to its helical axis so that the resiliency of said springs normally hold said convolutions in uniformly advancing spiral relation with each other and maintains said convolutions in firm frictional contact with said members, the width of each of said grooves in the direction of rotation exceeding the outside diameter of said convolutions so that said springs may roll during said rotational movement whereby rolling friction is encountered between said members and said spring contact.

15. In electrical apparatus a current interchange means comprising a pair of relative movable conductive members having opposed relatively planar surfaces in close proximity, means providing an elongate channel in one of said surfaces and having its open side disposed toward the other, a helical spring contact disposed in said channel, the helical axis of said spring being substantially linear, said channel and said spring being so arranged that a plane containing the helical axis of spring is perpendicular to the direction of said relative movement, the depth of said channel being substantially uniform and less than the outside diameter of said spring so that the convolutions thereof have their planes inclined at an angle relative to its helical axis, the resiliency of said spring normally holding said convolutions in firm frictional contact with said members, the width of said channel exceeding the diameter of said convolutions in the direction of relative movement of said members so that said spring may roll during the relative movement of said members whereby rolling friction is encountered between said surfaces and said spring contact.

16. Contact structure for use in electric switch means comprising a movable contact and a stationary contact assembly, said stationary contact assembly including a pair of conductive members, one of said conductive members comprising a contact block having a recess formed therein, the other conductive member comprising a contact finger received within said recess, a channel formed in one of said members and having its open side disposed toward the other member, a helical spring contact disposed in said channel, the depth of said channel being substantially uniform and less than the outside helical diameter of said spring so that the convolutions thereof have their planes inclined at an angle relative to its helical axis, the resiliency of said spring normally holding said convolutions in firm frictional contact with said members, the width of said channel in the direction of movement of said other member being approximately equal to the diameter of said convolutions plus one-half the distance between said first and second positions so that said spring rolls during the movement of said other member between said first and second positions whereby rolling friction is encountered between said members and said spring contact.

17. Contact structure for use in electric switch means comprising a movable contact and a stationary contact assembly having a pair of conductive members, one of said conductive members comprising a contact block having a recess formed therein, opposite walls of said recess being substantially planar, the other conductive member comprising a contact finger received within said

recess and having opposed substantially planar surfaces adjacent said opposite walls for movement between first and second positions, a groove formed in the planar portion of one of said members and having its open side disposed toward the other, a helical spring contact disposed in said groove with its helical axis substantially parallel to said planar surface and lying in a plane substantially perpendicular to the direction of said movement, the depth of said groove being less than the helical diameter of said spring so that the convolutions thereof have their planes inclined at an angle relative to its helical axis, whereby the resiliency of said spring normally holds said convolutions in uniformly advancing spiral relation with each other and maintains said convolutions in firm frictional contact with said members, the width of said groove in the direction of movement of said contact fingers being approximately equal to the diameter of said convolutions plus one-half the distance between said first and second positions so that said spring rolls during the movement of said contact finger between said first and second positions whereby rolling friction is encountered between said members and said spring contact.

18. Contact structure for use in electric switch means comprising a movable contact and a stationary contact assembly having first and second conductive means, said first conductive means comprising a contact block having a recess formed therein, opposite walls of said recess being substantially planar, said second conductive means comprising a plurality of contact fingers disposed within said recess in side-by-side relation and each having opposed substantially planar surfaces adjacent said opposite walls, for movement between first and second positions, a groove formed in the planar portion of one of said conductive means and having its open side disposed toward the other, a plurality of helical spring contacts disposed in said groove with their helical axes substantially parallel to each other and to said planar walls and lying in planes substantially perpendicular to the direction of said movement, the depth of said grooves being less than the helical diameters of said springs so that the convolutions thereof have their planes inclined at an angle relative to its circumferential axis, whereby the resiliency of said springs normally hold said convolutions in uniformly advancing spiral relation with each other and maintains said convolutions in firm frictional contact with said contact block and said contact fingers, each of said springs being inclined in an opposite direction relative to each spring adjacent thereto to prevent intermingling of their convolutions, the width of said groove in the direction of movement of said contact fingers being approximately equal to the sum of the helical diameters of each of said springs plus one-half the distance between said first and second positions so that said spring rolls during the movement of said other member between said first and second positions whereby rolling friction is encountered between said members and said spring contact.

19. Contact structure for use in electrical switch means comprising a movable contact and a stationary contact assembly, said stationary contact assembly including a pair of conductive members, one of said conductive members comprising a contact block having a substantially planar surface, the other conductive member comprising a contact finger mounted adjacent said surface for movement in a direction substantially parallel thereto, a groove formed in one of said members and having its open side disposed toward the other, a helical spring contact disposed in said groove, the distance between said members across said groove being substantially uniform and shorter than the outside diameter of said spring so that the convolutions thereof have their planes inclined at an angle relative to its helical axis so that the resiliency of said spring normally holds said convolutions in firm frictional contact with said members, the width of said groove in the direction of movement of said other member being greater than the outside diameter of said convolutions in the direction of relative movement of said members so that said spring may roll during such movement.

**References Cited** in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 959,435 | Thomson | May 24, 1910 |
| 2,198,039 | Onions et al. | Apr. 23, 1940 |
| 2,203,806 | Wolf | June 11, 1940 |
| 2,449,479 | Hopper et al. | Sept. 14, 1948 |
| 2,525,730 | Schulze | Oct. 10, 1950 |
| 2,615,077 | Tinker | Oct. 21, 1952 |
| 2,965,734 | Timmerman | Dec. 20, 1960 |
| 2,975,254 | Yanagisawa | Mar. 14, 1961 |

FOREIGN PATENTS

| | | |
|---|---|---|
| 29,822 | Great Britain | June 24, 1914 |
| 186,526 | Great Britain | Oct. 5, 1922 |
| 685,738 | Germany | Dec. 23, 1939 |
| 511,967 | Italy | Jan. 28, 1955 |
| 962,083 | Germany | Apr. 18, 1957 |
| 1,007,576 | Germany | May 2, 1957 |