April 30, 1940. A. M. ROSSMAN 2,198,635

STRAIGHT LINE OPERATING MECHANISM

Filed Aug. 15, 1938 3 Sheets-Sheet 1

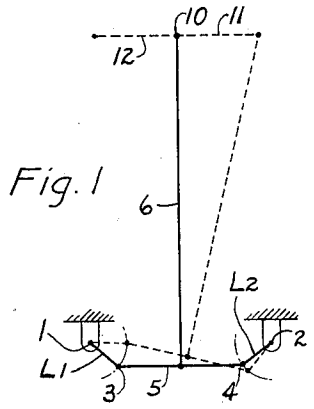


Fig. 1

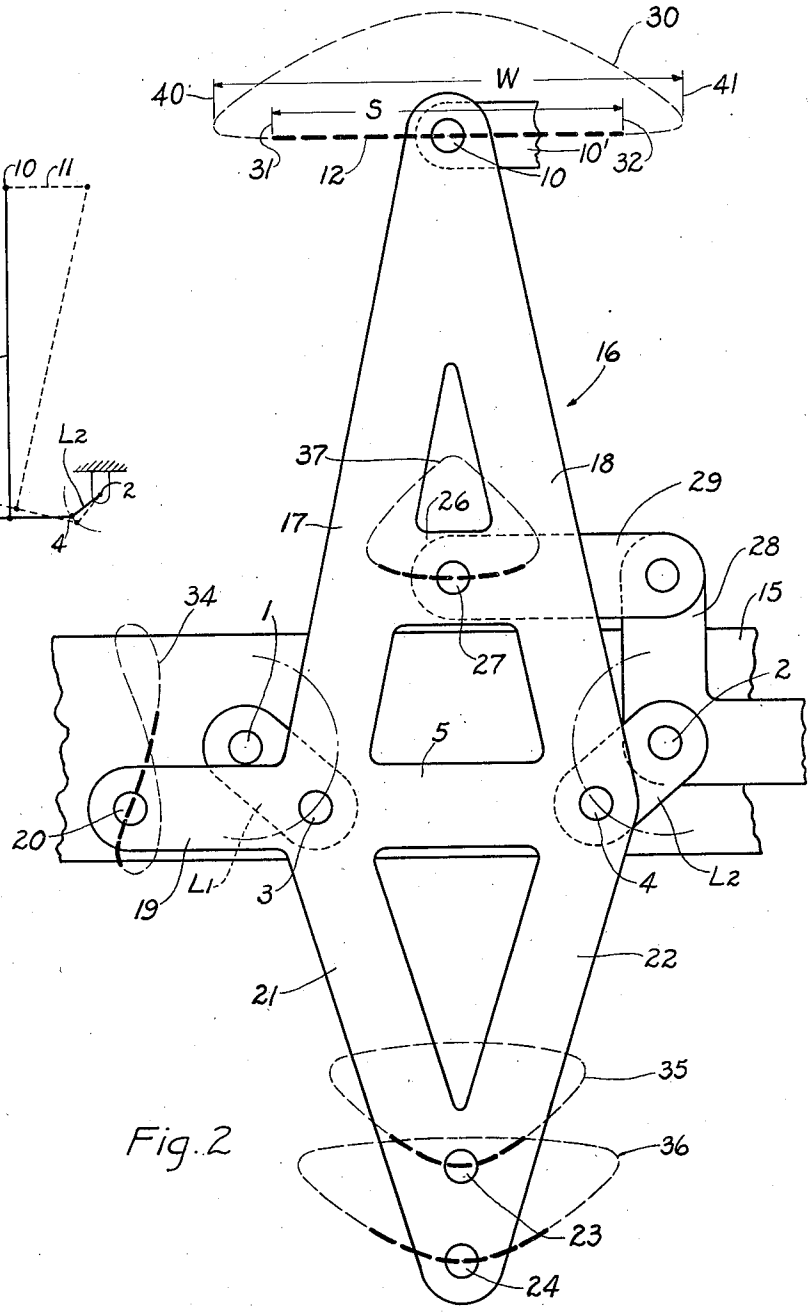


Fig. 2

INVENTOR.
Allen M. Rossman
BY Morris Spector
ATTORNEY

April 30, 1940. A. M. ROSSMAN 2,198,635

STRAIGHT LINE OPERATING MECHANISM

Filed Aug. 15, 1938 3 Sheets-Sheet 2

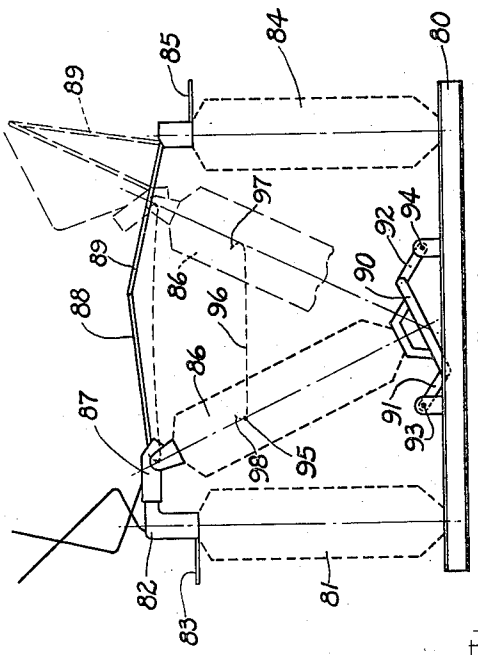


Fig. 5

Fig. 3

INVENTOR.
Allen M. Rossman
BY Morris Spector,
ATTORNEY.

April 30, 1940. A. M. ROSSMAN 2,198,635

STRAIGHT LINE OPERATING MECHANISM

Filed Aug. 15, 1938 3 Sheets-Sheet 3

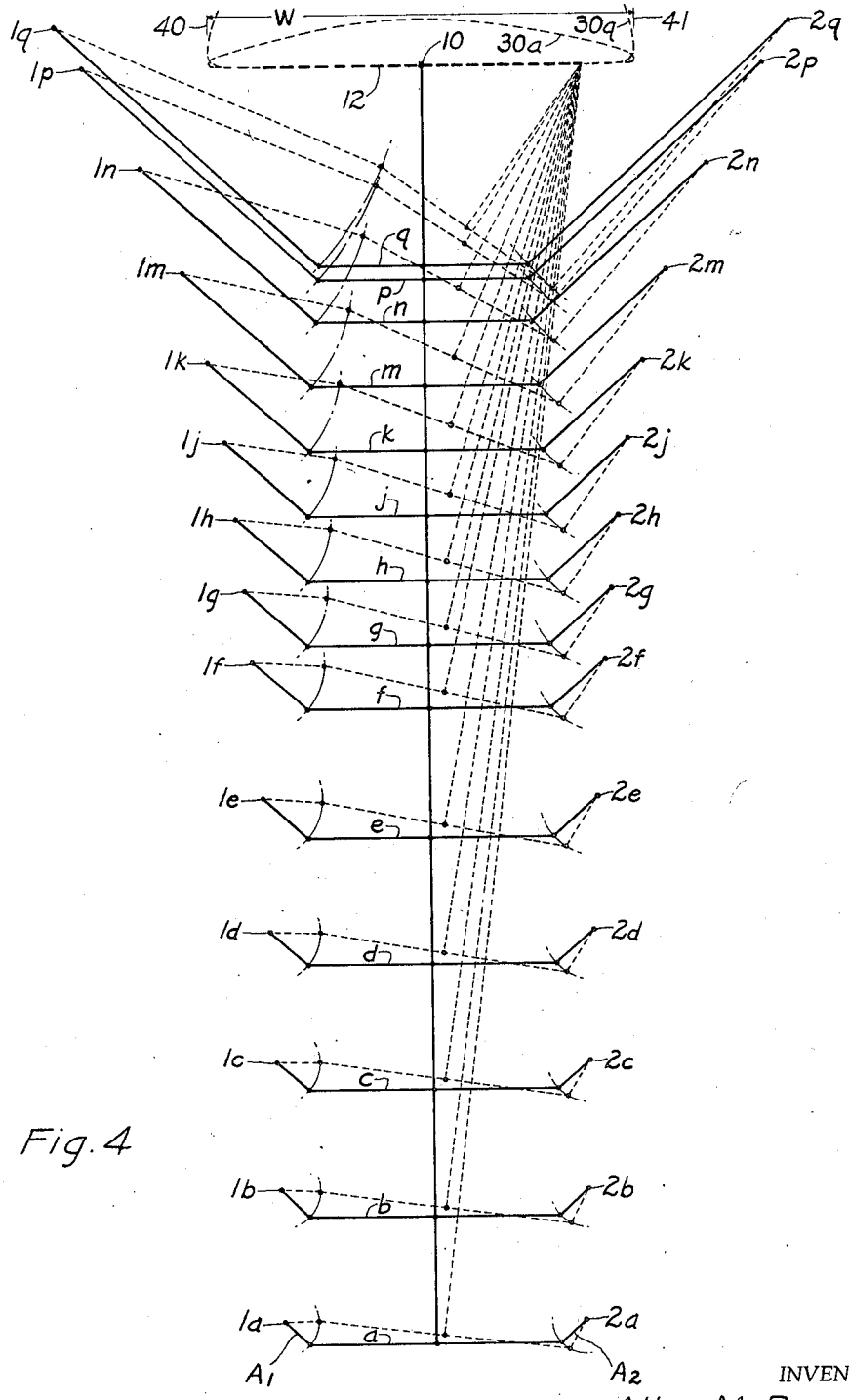


Fig. 4

INVENTOR.
Allen M. Rossman
BY Morris Spector,
ATTORNEY.

Patented Apr. 30, 1940

2,198,635

UNITED STATES PATENT OFFICE

2,198,635

STRAIGHT LINE OPERATING MECHANISM

Allen M. Rossman, Wilmette, Ill.

Application August 15, 1938, Serial No. 224,862

14 Claims. (Cl. 74—103)

This invention relates to linkages for producing straight line motions, and more particularly to simple linkages pivoted about two spaced fixed pivots and so proportioned that upon rotation of one or more of the links a given point on the linkage will move on a straight line. It is one object of the present invention to provide such a linkage wherein the length of the resulting straight line is a maximum for links of a given size.

I have discovered that if there is provided a linkage having two equal links pivoted about spaced fixed pivots, with a third link connecting the two links, and those links are of definite relationship to each other then one point on the perpendicular bisector of the third link will move a maximum distance in a straight line upon actuation of the linkage.

The attainment of the above and further objects of the present invention will be apparent from the following specification taken in connection with the accompanying drawings.

In the drawings:

Figure 1 is a diagrammatic view illustrating a linkage embodying the present invention;

Figure 2 is a somewhat larger view illustrating an actual construction of a linkage embodying the present invention;

Figure 3 consists of a series of interrelated graphs from which can be read the ratios of the various interrelated dimensions for obtaining the maximum straight line in linkages of various proportions;

Figure 4 shows, in diagrammatic form, a family of linkages embodying the invention, superimposed to illustrate the correlation between linkages of different proportions; and

Figure 5 shows a linkage of the present invention applied to a disconnecting switch.

Reference may be had more particularly to the diagrammatic illustration in Figure 1. In this figure I have shown two equal links, indicated by the letters L1 and L2, pivoted about fixed pivots 1 and 2, respectively, and having the movable pivots 3 and 4 of the two links pivotally connected by a bar or member 5. A rod or extension 6 is rigid with the bar 5 and extends perpendicular thereto at the midpoint of the bar 5 so that the rod 6 constitutes a perpendicular bisector of the bar 5. I have discovered that with a given spacing of fixed pivots 1 and 2 and a given length of links L1 and L2 there will be one point on the perpendicular bisector 6 which moves in a straight line as the links L1 or L2 are turned. This point is indicated in Figure 1 by the reference numeral 10. If the link L1 is rotated in a counter-clockwise direction from the position indicated in full lines to the position indicated in dotted lines the point 10 will move along the straight line indicated by the reference numeral 11. Similar clockwise movement of the link L2 will cause a like equal movement of the point 10 to the left instead of to the right. I have found that within the limits of the curves shown in Figure 3 the maximum length of straight line of travel for a point on the rod 6 is obtained when the lengths of the links L1 and L2 are each made .667 times the difference of the distance of the fixed points 1—2 and the movable points 3—4. This means that when the link 5 is in its center position where it is parallel with the line between the fixed pivots 1—2, the link L1 will make an angle 41° 24.6′ with the line joining the fixed points 1—2 within the limits of the curves of Figure 3. The distance between the fixed points should be .8 of the desired length of straight line plus 1.333 times the length of the link L1. The reference numeral 12, which represents the locus of the point 10, marks the maximum straight line which can be obtained with the linkage illustrated in Figure 1. If the fixed pivots 1—2 are spaced a lesser distance apart or the points 3—4 are spaced a greater distance apart, a point on the rod 6 can be found which will move in a straight line but the length of that straight line will be less than the length of the line 12. If the fixed points 1—2 are spaced a substantially greater distance apart, or the points 3—4 are spaced a substantially lesser distance apart, it will not be possible to find any point on the perpendicular bisector of the member 5 which will move in a straight line.

Reference may now be had to Figure 2 wherein there is illustrated an actual embodiment of the linkage of Figure 1. A stationary structure 15 supports the fixed pivots 1 and 2 for the equal links L1 and L2. A double triangular frame 16 is pivoted to the links L1 and L2 at the pivots 3 and 4, said frame including a bar 5 from which extend arms 17 and 18 of equal lengths so that the point 10 on the arms 17—18 is on the perpendicular bisector of the portion of the frame 16 that lies between the movable pivots 3—4. The bar 5 is also provided with an extension 19 rigid therewith which has a hole 20 therein for receiving a pin of an actuator. Likewise the frame is provided with equal arms 21—22 providing holes 23—24 for receiving a pin to be connected to an actuator. The arms 17—18 may,

if desired, be connected intermediate their ends by a cross brace 26 which is also provided with a pin-receiving opening 27 for receiving an actuator. Thus the actuator can be connected to the frame 16 at the holes 10, 20, 23, 24 or 27, or to any other part thereof. The actuator may consist of a crank 28 pivoted about a stationary axis and a link 29 pivoted thereto and to the frame 16 at one of the holes 10, 20, 23, 24 or 27 selectively. In the embodiment illustrated, the crank 28 is pivoted about the stationary pivot 2, and the link 29 is pivoted to the frame 16 at 27. The pivot axis for the crank 28 may be located at any point desired, and need not be coincident with the pivot axis for the link L2. A movable element 10' whose motion at the end is to be kept in a straight line is pivoted to the frame 16 at 10.

If the links L1 or L2 are rotated about their fixed pivots the center of the control point 10 will move in a locus indicated by the dotted line 30. When the mechanism is in any position with the control point 10 between the limits 31—32, a line drawn from the point of intersection of center lines 1—3 and 2—4 extended and perpendicular to the center line 1—2 will pass through the center of control point 10. The portion 12, indicated in heavy lines, from the point 31 to the point 32, is therefore a straight line parallel to the center line 1—2. As the point 10 moves in the locus indicated at 30, the centers of the openings 20, 23, 24 and 27 move in loci indicated by the dotted lines 34, 35, 36 and 37 respectively. In each one of these loci the heavy lines indicate the portions of the path of movement which corresponds to the movement of the point 10 between the points 31—32.

It is to be noted that the curve 36 is much longer from left to right than the curve 35 but both have the same depth. Curves similar to the curves 35 and 36 representing the loci of points corresponding to the points 23—24 but located appreciably closer to the link 5 would have a lesser and lesser length in a direction from left to right, as seen in Figure 2, and the same height from top to bottom, as seen in Figure 2.

Symbols which are used in the following formulas are defined below, with reference to Figure 2.

W=overall width of the locus line 30 between the parallel tangents 40 and 41;
S=length of straight line portion of 30;
L=length of each link L1 and L2;
A=length of perpendicular from point 10 to the center line through 3—4;
H_f=spacing of fixed hinges 1—2;
H_m=spacing of movable hinges 3—4.

I have found that within the limits of the curves shown in Figure 3 the maximum straight line will be obtained if the linkage is constructed in accordance with the following formulae:

(1) $W=2.095\sqrt{AL}-.37\ L$

(2) $S=.75\ W$. The limits of the straight line portion of W are not easily discernible. 75% of W can be regarded as conservative.

(3) $H_f=.6W+1.333\ L$.

(4) $H_m=.6W-.1667\ L$.

(5) $L=\frac{H_f-H_m}{1.5}$

Formulae 1, 3 and 4 are empirical, but have been found to check with experimental data within the limits of error of the experimental data.

An explanation will now be given of the manner of using the curves of Figure 3 in order to ascertain the interrelation of dimensions for obtaining linkages which will give maximum lengths of straight line. Assume that a straight line S of a length equal to 100 units of length by any unit of measure is desired, and the length of the perpendicular arm, which is the arm 6 of Figure 1, is known in terms of percentage of the length of the straight line. The abscissa 50 represents the length of the perpendicular arm, the ordinates 51 represent the corresponding lengths of the other dimensions. The curve indicated by the reference numeral L indicates the length of each of the equal links L1 and L2. The curve indicated by the reference numeral H_m indicates the spacing between the movable pivots 3 and 4. The curve indicated by the character H_f indicates the spacing between the fixed pivots 1 and 2. The line S indicates the length of the straight line portion 12 of Figure 2, which is taken as 100%. Assume arbitrarily that the length of the perpendicular arm 6 is to be 157% of the length of the straight line. By noting the various intersections of the vertical line which passes through the point 157 on the abscissa we find that the length of the links L should be 30, the distance between the movable pivots H_m should be 75 and the distance between the fixed pivots should be 120, all expressed as a percentage of the length of the straight line. Values obtainable from these curves enable the construction of a linkage which will give a straight line of the maximum length for that particular length of perpendicular arm.

Reference may now be had more particularly to Figure 4 wherein I have shown, in diagrammatic form, a series of links each of which is constructed so that one point on the link will move in a straight line 12. As has been previously stated, the length of the straight line portion of the locus point is a function of the lengths of the various members of the linkage and the spacing of the joints. For each given length of links and a corresponding spacing of the pivots on the suspension member there is a minimum length of suspension member which, by proper adjustment of the spacing on the link joints on the stationary structure, will give a maximum length of straight line. The sizes of the various links for giving a maximum length of straight line, as determined from the curves of Figure 3, have been indicated in Figure 4. In this figure the length of the straight line is indicated at 12 and is taken as 100% or 100 units of length. Consider, by way of example, the linkage comprising the equal links A_1 and A_2 swinging about the fixed pivots 1 and 2 and joined by a movable member a. The point 10 is on the perpendicular bisector of the member a, and the length of the perpendicular bisector is taken at any arbitrary value on the abscissa 50 of Figure 3. The lengths of the swinging links A_1 and A_2 and the lengths of the movable member a, and the distance between the fixed pivots 1 and 2, corresponding to the arbitrarily chosen distance of the point 10 from the movable member a, are ascertained from the curves of Figure 3. The complete locus of travel of the point 10 for the linkage a is indicated at 30_a. Another linkage b whose constants are also determined from the

curves of Figure 3 for a different value of abscissa or length of perpendicular bisector, is then drawn in. Similarly, the linkages *c, d, e, f, g, h, j, k, m,* and *n* are drawn. In each instance the length of the perpendicular from the point 10 to the movable member corresponding to the link 5 is taken at some arbitrary value and the corresponding lengths of the links and distances between the fixed and movable pivots are ascertained from the curves of Figure 3.

In the linkage *p* the fixed pivots 1_p and 2_p are in line with the straight line portion 12 of the locus of the straight line motion point 10. In the linkage *q* the fixed pivots 1_q and 2_q are above the line 12. A portion of the locus of the point 10 of the linkage *q* is indicated at 30_q. This curve is of the same width W as the curve 30_a but is much higher. It also includes the straight line portion 12. If the curve is drawn through the fixed pivots 2_a to 2_n or through the corresponding movable pivots when they are in their central positions, the curves will be found to correspond, respectively, to the curves H_f and H_m of Figure 3. The linkage *n* corresponds to a length of perpendicular bisector equal to .8 of the length of straight line portion 12, or .8 of S on Figure 3. Values for linkages *p* and *q* lie on extensions to the left of the curves shown on Figure 3. Values of H_f and H_m can be found by the use of the formulas. Values of H_m were determined experimentally because on the extension, values of H_m derived by formula give a curve which diverges from the curve which experiment has demonstrated to be the true curve.

From a study of the links of Figure 4 it is to be noted that for every linkage the movable point 10 moves in a locus which lies entirely away from the fixed points 1 and 2. If a line is drawn from the locus point 10 to any movable pivot, such as, for instance, the movable pivot on the linkage *p*, the angle between this line and the floating member corresponding to the link 5 of Figure 1 will be less than the minimum possible angle between the same floating member 5 and either of the links that swing about a fixed pivot. As the point 10 moves to the right from the position illustrated in Figure 4 the left hand movable link pivoted at 1 restrains the linkage from assuming such a position that the point 10 coincides with the point 2.

From the family of linkages illustrated in Figure 4 it is apparent that it is possible to construct linkages of vastly different proportions and each having the same length of movement in a straight line, which length of movement is the maximum obtainable for each given perpendicular distance from the straight line point to the movable member 5 that is pivoted to the two links which swing about fixed axes. In some installations it may be desirable to locate the fixed pivots 1 and 2 rather far apart and have a comparatively short length of arm from the movable point to the floating link. In other instances it may be necessary to have a comparatively greater length of movable arm, in which case the distance between fixed pivots is less and the lengths of the swinging links are less.

While I have here shown a series of curves and data for obtaining a mechanism having a straight line motion of a maximum length, it is to be understood that the present invention is not limited to a mechanism wherein the maximum length of straight line is obtained. It is within the purview of the present invention to use linkages so proportioned as to obtain a straight line of less than maximum length possible for the height of mechanism used.

The straight line mechanism of the present invention is capable of a large number of applications. It may be used to transmit motion to, or to guide a moving part, or to fix the movement of any desired point on a mechanism in accordance with the laws of motion of the straight line mechanism above adduced. For instance, it may be used as part of the linkage for obtaining a straight line motion in a circuit breaker in lieu of the corresponding linkages, shown, by way of example, in the United States patent to Wallace, No. 1,001,716, or it may be used to guide the end of a piston rod in a straight line, in lieu of the usual cross head, as for instance, in the United States patent to Gerling, No. 1,831,490, or may be used for a like purpose to replace the cross head and guides of a locomotive in lieu of the straight line mechanism shown, for instance, in the United States patent to Burford, No.1,802,233. The swinging member may be made of any desired shape subject to the fundamental condition that the pivotal point 10 shall be located on the perpendicular bisector of the line joining the pivots 3 and 4.

In view of the fact that the frame 16 is a rigid frame the locus of any point on the frame has a fixed relationship to the locus of the point 10 on the frame. Therefore, if the frame 16 is mounted on a locomotive so that the point 10 guides the piston rod in lieu of the usual cross head, then the locus of any point on the frame 16 has a definite fixed relationship with respect to the position of the piston rod guide, corresponding to the position of the cross head in the usual locomotive. A point on the frame 16 may therefore be made to operate the steam engine valves, or to supply one of the motions required for the operation of the valves. The point on the frame 16 which controls the valves may be made closer to or farther from the bar 5 so that it will have a greater or lesser amount of motion as desired. This point is preferably, although not necessarily, chosen on the same side of the bar 5 as that on which the point 10 is located. In the usual locomotive cross head one end of the member actuated by the cross head for controlling the actuation of the steam valves moves a distance equal to the distance of travel of the cross head. By the present arrangement a point on the frame 16, between the arms 17 and 18, can be obtained which moves a much lesser distance than the distance of travel of the point 10, which represents the stroke of the piston, and yet bears a definite relationship to the movement of the piston rod.

In each of the above illustrations the point which moves on a straight line is pivoted to other parts of a mechanism either to impart a straight line motion to the other parts of the mechanism or to guide those parts in a straight line motion. The straight line mechanism of the present invention may also be used in a structure where the straight line moving point 10 is not pivoted to any other structure. Such an arrangement is shown in Figure 5 which shows, diagrammatically, an electric disconnecting switch of the rocking insulator type. In this type of switch the rocking insulator swings through an arc from its open to its closed position. In such switches as were heretofore constructed this swinging movement involved a change in elevation of the center of gravity of the rocking insulator, with a resulting

change in the potential energy thereof. By constructing the switch in the manner shown in Figure 5 so that points close to the center of gravity of the moving system move in a straight line, horizontally, in accordance with the present invention, there is little change in the potential energy of the moving system. The switch illustrated in Figure 5 comprises the usual grounded metallic base 80 which consists of two spaced channels, upon which are mounted a stationary insulator 81 carrying a fixed switch contact 82 and a line terminal 83 and a second stationary insulator 84 carrying a line terminal 85. A rocking insulator 86 carries a contact structure 87 adapted to cooperate with the contact 82 to establish a circuit from the line terminal 85 through a flexible conductor (not shown) supported by a pair of links 88—89 pivoted together and pivoted to the top of the insulator 84 and the top of the insulator 86, thence through the pair of cooperating contacts 87—82 to the opposite line terminal 83. The insulator 86, shown diagrammatically, includes the usual petticoats carrying an insulator cap at the top thereof on which the contact 87 is mounted, the petticoats themselves being supported by the usual insulator pin. The rocking insulator is mounted upon a link 90 that is supported by two equal short links 91 and 92 pivotally joined thereto and pivotally supported about fixed pivots 93 and 94. The point 95 on the rocking insulator 86 represents the center of gravity of the movable system and it is located on the perpendicular bisector of the link 90 and constitutes the point on the perpendicular bisector which moves in a horizontal straight line, indicated at 96. The rocking insulator is rocked to its open position by imparting a rotary motion to either the link 91 or the link 92, or by means of an extension on the connecting link 90. During this motion the center of gravity of the movable system moves substantially horizontally. Toward the end of the switch opening movement the center of gravity 95 tends to rise upon the curved portion 97. This would require an additional amount of potential energy and this characteristic therefore serves to decelerate the switch in its open position without banging or shock. Likewise, when the contact reaches its closed position any further movement of the contact in its closed position would cause the center of gravity of the system to rise along the portion of the curve indicated at 98. This would require additional potential energy and this therefore serves to decelerate the switch in its closing direction without jarring or shock. While the switch is open the links 88—89 assume the position indicated in dotted lines, as is usual with the switches of this type.

It is to be noted that the support for the rocking insulator and its associated parts consists essentially of the linkage shown in Figure 2, namely, two fixed pivots to which are pivoted two equal links which are in turn joined by a third link of lesser length than the distance between the fixed pivots, with the point that is to have a straight line motion located on the perpendicular bisector of that third link.

In compliance with the requirements of the patent statutes I have here shown and described a preferred embodiment of my invention. It is, however, to be understood that the invention is not limited to the precise construction here shown, the same being merely illustrative of the principles of the invention.

What I consider new and desire to secure by Letters Patent is:

1. Straight-line motion apparatus comprising a pair of links pivoted to swing about spaced fixed parallel pivots, a movable member pivotally joining the links to swing about two parallel movable pivots spaced a distance apart less than the distance between the two fixed pivots, both movable pivots being on the same side of a plane determined by the fixed parallel pivots, each link being of a length of the order of two-thirds of the difference between the spacing of the fixed pivots and the spacing of the movable pivots, and a straight-line control point on the movable member having a straight-line motion and located on the perpendicular bisector of a line joining the movable pivots.

2. Straight-line motion apparatus comprising a pair of links pivoted to swing about spaced fixed parallel pivots, a member pivotally joining the links to swing about two parallel movable pivots spaced a distance apart less than the distance between the two fixed pivots, both movable pivots being on the same side of a plane determined by the fixed parallel pivots, each link being of a length of the order of two-thirds of the difference between the spacing of the fixed pivots and the spacing of the movable pivots, the distance between the movable pivots being greater than the length of each link, and a straight-line control point on the movable member having a straight-line motion and located on the perpendicular bisector of a line joining the movable pivots.

3. Straight-line motion apparatus comprising a pair of links pivoted to swing about spaced fixed parallel pivots, a member pivotally joining the links to swing about two parallel movable pivots spaced a distance apart less than the distance between the two fixed pivots, both movable pivots being on the same side of a plane determined by the fixed parallel pivots, each link being of a length of the order of two-thirds of the difference between the spacing of the fixed pivots and the spacing of the movable pivots, the distance between the movable pivots being greater than 1.5 times the length of each link, and a straight-line control point on the movable member having a straight-line motion and located on the perpendicular bisector of a line joining the movable pivots.

4. Straight-line motion apparatus comprising a pair of links pivoted to swing about spaced fixed parallel pivots, a member pivotally joining the links to swing about two parallel movable pivots spaced a distance apart less than the distance between the two fixed pivots, both movable pivots being on the same side of a plane determined by the fixed parallel pivots, each link being of a length of the order of two-thirds of the difference between the spacing of the fixed pivots and the spacing of the movable pivots, the distance between the movable pivots being greater than twice the length of each link, and a straight-line control point on the movable member having a straight-line motion and located on the perpendicular bisector of a line joining the movable pivots.

5. Straight-line motion apparatus comprising a pair of links pivoted to swing about spaced fixed parallel pivots, a member pivotally joining the links to swing about two parallel movable pivots spaced a distance apart less than the distance between the two fixed pivots, each link being of a length of the order of two-thirds of

the difference between the spacing of the fixed pivots and the spacing of the movable pivots, and a straight-line control point on the movable member having a straight-line motion and located on the perpendicular bisector of a line joining the movable pivots and spaced from such line in excess of 1.5 times the distance between the movable pivots.

6. Straight-line motion apparatus comprising a pair of links pivoted to swing about spaced fixed parallel pivots, a member pivotally joining the links to swing about two parallel movable pivots spaced a distance apart less than the distance between the two fixed pivots, the distance between the movable pivots being greater than the length of each link, and a straight-line control point on the movable member having a straight-line motion and located on the perpendicular bisector of a line joining the movable pivots and spaced from such line in excess of 1.5 times the distance between the movable pivots.

7. Straight-line motion apparatus comprising a pair of links pivoted to swing about spaced fixed parallel pivots, a member pivotally joining the links to swing about two parallel movable pivots spaced a distance apart less than the distance between the two fixed pivots, both movable pivots being on the same side of a plane determined by the fixed parallel pivots, and a straight-line control point on the movable member having a straight-line motion and located on the perpendicular bisector of a line joining the movable pivots and spaced from each movable pivot substantially different from the distance between each movable pivot and an adjacent fixed pivot.

8. A straight-line motion apparatus comprising a movable member, means for guiding two spaced points on said member to move in separate circular arcs of equal radii and whose centers are spaced apart an amount substantially different from the distance between the two points, a straight-line control point on the movable member having a straight line motion for at least a portion of its travel and located on the perpendicular bisector of a line joining the two spaced points, the distance between the centers of the arcs and the distance between the two spaced points and the length of the perpendicular bisector being so correlated that the entire possible closed curve of the locus of travel of the control point is spaced from the centers of said arcs.

9. A straight-line motion apparatus comprising a movable member, means for guiding two spaced points on said member to move in separate circular arcs of equal radii and whose centers are spaced apart and amount substantially different from the distance between the two points, a straight line control point on the movable member having a straight line motion for at least a portion of its travel and located on the perpendicular bisector of a line joining the two spaced points, the angle between a line joining the spaced points and a line from the control point to one of the spaced points being less than the minimum angle between said line joining the spaced points and one of said radii even when the extent of movement of said apparatus is unrestricted.

10. A straight-line motion apparatus comprising a fixed member, a movable member, a pair of links of equal length, each link being secured to each of said members by a hinge joint, the four hinge joints having parallel hinge pins, and a straight line control point located on the perpendicular bisector of a line joining the two hinges of the movable member and spaced from such joining line and amount in excess of half the length of such joining line, the spacing of the hinges on the movable member being greater than one-half of the spacing of the hinges on the fixed member.

11. Straight-line motion apparatus comprising a pair of links pivoted to swing about spaced fixed parallel pivots, a member pivotally joining the links to swing about two parallel movable pivots spaced a distance apart less than the distance between the two fixed pivots, both movable pivots being on the same side of a plane determined by the fixed parallel pivots, and a straight-line control point on the movable member having a straight-line motion and located on the perpendicular bisector of a line joining the movable pivots and spaced from each movable pivot substantially different from the distance between each movable pivot and an adjacent fixed pivot, and the effective length along each link between a fixed pivot and an adjacent movable pivot being less than the difference between the distance separating the fixed pivots and the distance separating the movable pivots.

12. Straight-line motion apparatus comprising a pair of links pivoted to swing about spaced fixed parallel pivots, a member pivotally joining the links to swing about two parallel movable pivots spaced a distance apart less than the distance between the two fixed pivots, both movable pivots being on the same side of a plane determined by the fixed parallel pivots, and a straight-line control point on the movable member having a straight-line motion and located on the opposite side of said plane and on the perpendicular bisector of a line joining the movable pivots and spaced from each movable pivot substantially more than the distance between each movable pivot and an adjacent fixed pivot, and the effective length along each link between a fixed pivot and an adjacent movable pivot being less than half the distance separating the fixed pivots.

13. Straight-line motion apparatus comprising a pair of links pivoted to swing about spaced fixed parallel pivots, a member pivotally joining the links to swing about two parallel movable pivots spaced a distance apart of the order of one-third the distance between the two fixed pivots, both movable pivots being on the same side of a plane determined by the fixed parallel pivots, and a straight-line control point on the movable member having a straight-line motion and located on the perpendicular bisector of a line joining the movable pivots where said perpendicular bisector intersects the plane determined by the fixed parallel pivots and spaced from each movable pivot substantially different from the distance between each movable pivot and an adjacent fixed pivot, said links being of equal effective lengths and less than half the length between the fixed parallel pivots.

14. Straight-line motion apparatus comprising a pair of links pivoted to swing about spaced fixed parallel pivots, a member pivotally joining the links to swing about two parallel movable pivots spaced a distance apart less than the distance between the two fixed pivots, both movable pivots being on the same side of a plane determined by the fixed parallel pivots, and a straight-line control point on the movable member having a straight-line motion and located on the

same side of said plane and on the perpendicular bisector of a line joining the movable pivots and spaced from each movable pivot substantially less than the distance between each movable pivot and an adjacent fixed pivot, and the effective length along each link between a fixed pivot and an adjacent movable pivot being less than the difference between the distance separating the fixed pivots and the distance separating the movable pivots.

ALLEN M. ROSSMAN.