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ELECTROMAGNETIC RECIPROCATING MOTOR

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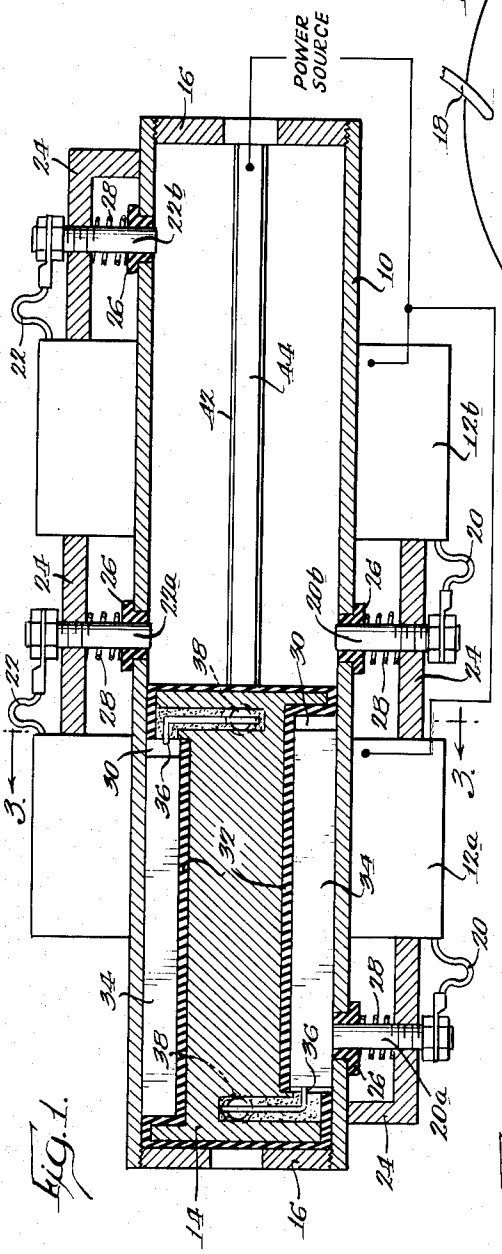


Fig. 1.

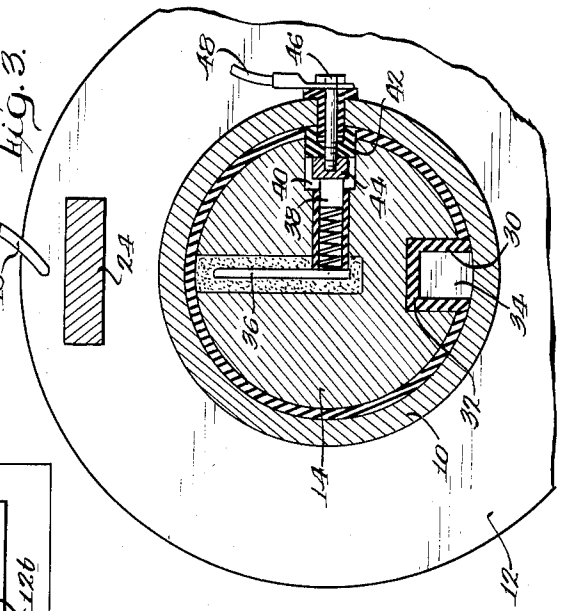


Fig. 3.

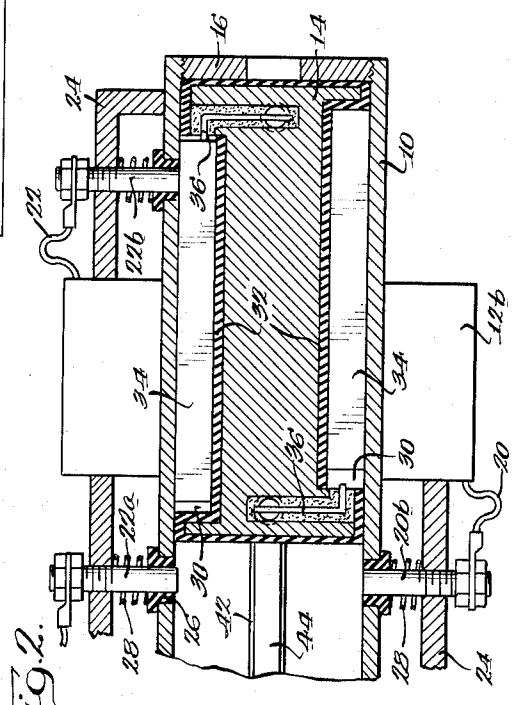


Fig. 2.

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ELECTROMAGNETIC RECIPROCATING MOTOR

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The present invention relates to electromagnetic rectilinear accelerators and motors, and particularly, to an improved, self-contained, A.C.–D.C. electromagnetic reciprocating motor.

Electromagnetic rectilinear accelerators and motors are generally comprised of a cylinder, a permeable armature slidable in the cylinder and a plurality of electromagnetic coils spaced along the cylinder and energized sequentially in such manner as to draw or pull the armature in a given direction as the coils are energized in sequence in such direction. The sequential energization of the coils has heretofore been effected in two ways, namely, (1) by reliance upon the periodicity of alternating current sources, involving of course auxiliary control apparatus, and (2) by use of a switching device operated by an auxiliary rotary motor.

The object of the present invention is to provide an improved electromagnetic reciprocating motor that does not require auxiliary equipment, that is completely self-contained, and that is not reliant on an A.C. supply but is directly connectable to any conventional A.C. or D.C. power supply; in other words, a self-contained, universal, electric reciprocating motor that may be embodied in any desired size, at substantially any desired power and with substantially any desired reciprocatory stroke and speed, and that may, for example, be made portable and embodied in a wide variety of products, such as portable reciprocatory power tools.

It is specifically an object of this invention to provide an improved electromagnetic reciprocating motor including a cylinder, one or more coils on the cylinder and an armature on the cylinder actuated upon energization of the coil or coils, characterized in that energization of the coils in properly timed relation to armature reciprocation is governed by switching means incorporated in the motor armature.

A further object of the invention is the provision of an improved electromagnetic reciprocating motor as aforesaid including one or more coils on the cylinder each connected to one side of either an A.C. or D.C. power supply and including a pair of circumferentially spaced contacts projecting into the cylinder, the contacts of the coil or coils defining two separate sets of stationary contacts, and switch means on the armature having connection to the other side of the power supply and responsive to movement of the armature to opposite ends of the cylinder for alternately energizing a pair of circumferentially spaced armature contacts that are respectively engageable with the contacts of the two stationary sets, whereby to energize the coil or coils first through one set of contacts in the direction to move the armature to one end of the cylinder, whereupon the switch is actuated, and then to energize the coil or coils through the other set of contacts in the opposite direction to move the armature to the other end of the cylinder, whereupon the switch is again actuated to initiate repetition of the reciprocatory movement described.

A still further object of the invention is to embody the improved motor above defined in a compact, economical and portable assembly for convenient commercial and industrial use.

Other objects and advantages of the invention will become apparament in the following detailed description.

Now, in order to acquaint those skilled in the art with the manner of making and using my improved electromagnetic reciprocating motor, I shall describe, in connection with the accompanying drawings, a preferred embodiment of the motor and the preferred manners of making and using the same.

In the drawings:

FIGURE 1 is a vertical longitudinal section of a universal electromagnetic reciprocating motor embodying the present invention, the view showing the armature in one end position;

FIGURE 2 is a fragmentary longitudinal section of the motor showing the armature in its other end position; and

FIGURE 3 is an enlarged cross-sectional view of the motor taken substantially on line 3—3 of FIGURE 1.

Referring now to the drawings, my improved motor in its preferred embodiment is comprised of a non-magnetic cylinder **10**, a plurality of electric coils **12** surrounding said cylinder in spaced relation to one another and the ends of the cylinder, a permeable armature **14** reciprocably mounted in the cylinder, and switch means (to be described in detail hereinafter) mounted principally on the armature for governing energization of the coils. The coils **12** and armature **14** are conventional elements of both the reciprocatory electric motor and solenoid arts, and electrical design parameters therefor may be determined from said arts. The object of the present invention is the provision of improved switch means for electromagnetic reciprocating motors, and the detailed description is therefore directed primarily to said switch means and the physical combination thereof with the cylinder **10**, the coils **12** and the armature **14**.

The cylinder **10** may be formed of any suitable non-magnetic material, metallic or non-metallic, and may take the form of a cylinder of circular section (as shown herein), a square or polygonal tube, a simple framework for guiding reciprocable movement of the armature, or the like. Irrespective of its form, the cylinder is provided at or adjacent its ends with abutments **16** that extend into the path of reciprocable movement of the armature for defining the end limits of armature travel. In the case of a circular cylinder as shown herein, the abutments may suitably comprise apertured discs or washers threaded into the ends of the cylinder, the apertures venting air from the cylinder whereby movement of the armature will be unimpeded. In a proper design, the abutments **16** could comprise sealed end closures and the cylinder could contain air, be evacuated, or be filled with a selected fluid for purposes of governing armature movement.

The coils **12** are of conventional cylindrical or torroidal form and are constructed in accordance with established standards of the art to produce from the selected or available supply of electric power the desired magnetic influence on the armature for pulling the armature into a centered position relative to the coil. The coils are secured in any suitable manner to the exterior surface of the cylinder. The number, size and placement of the coils are dependent upon the size and the reciprocatory stroke of the armature, and are herein shown as two in number, namely, **12***a* and **12***b*. Each coil has three taps comprising a main tap or lead **18** (FIGURE 3) to be connected to one side of the power supply and a pair of taps **20** and **22** extending from opposite sides and circumferentially spaced areas of the coil. In essence, tap **18** is connected to or comprises one end of the wire forming the respective coil, and the taps **20** and **22** are connected adjacent, or together comprise, the other end of such wire. Each of the taps **20** and **22** of each coil is connected to a respective contact, which are indicated at **20***a* and **22***a* and **20***b* and **22***b*, respectively, for the two coils **12***a* and **12***b* of the two-coil motor illustrated herein.

Each of the contacts is disposed radially of the cylinder, the same being mounted on box-like structures **24**

which are fixedly secured to the coils and the cylinder. Each contact projects radially through the wall of the cylinder 10, and in the case of conductive cylinder materials is insulated therefrom by an insulative grommet 26 held in place by a spring 28 confined between the grommet and the respective structure 24. The contacts project only a slight distance inwardly from the cylinder wall, and are preferably adjustably mounted on the structures 24 to accommodate proper adjustment of the contacts and to compensate for contact wear.

The contacts 20*a* and 20*b* are aligned with one another longitudinally of the cylinder to define one set of longitudinally spaced stationary contacts located to one side of their respective coils, and the contacts 22*a* and 22*b* are aligned longitudinally of the cylinder in circumferentially spaced relation to the contacts 20*a* and 20*b* to define a second set of longitudinally spaced stationary contacts located to the opposite side of their respective coils. While the two sets of contacts may be spaced any desired circumferential distance, the same have been shown herein as spaced 180 degrees thereby to define a lower set of contacts 20*a* and 20*b* and upper set of contacts 22*a* and 22*b*.

The armature 14 comprises a slug of permeable material of a size and configuration corresponding to the interior size and configuration of the cylinder 10, the same in the disclosed embodiment comprising a solid cylindrical slug of iron. Mounted on or in this slug is the switch means of the invention, the mount therefor in the preferred embodiment being defined by a pair of radially open longitudinally elongated slots 30 in the peripheral wall of the armature. The two slots 30 are spaced circumferentially from one another by the same arcuate distance (in this case 180 degrees) as the stationary contacts on the cylinder, whereby the slots are aligned respectively with two sets of contacts 20*a*–20*b* and 22*a*–22*b*. Both slots are lined at all but one end face thereof with insulating material, as indicated at 32, one end face of one slot and the other end face of the other slot being left exposed. Preferably, substantially the entire surface of the armature is encased in insulation. The insulation may suitably be one having a low cofficient of friction, such as "Teflon" or "Delrin," whereby to form bearing means for the reciprocable armature and also to cushion the impact of the armature against the abutments 16.

Slidably mounted for longitudinal movement in each of the slots 30 is an elongate contact bar 34 of significant mass. Each bar is shorter than the slot in which it is received and has freedom for endwise movement in its respective slot and is exposed at the periphery of the armature for contacting engagement with a respective set of stationary contacts 20*a*–20*b* and 22*a*–22*b*. Extending through the non-insulated wall of each slot 30 is a fixed contact 36 which is insulated from and extends radially inwardly to the center of the armature, one of said contacts being located at one end of one slot and the other being located at the other end of the other slot. Upon movement of the armature toward either end of the cylinder, the armature and the two contacts 34 gain momentum. When the armature is suddenly stopped by engagement with an abutment 16, the contacts 34 due to their momentum continue to move in the initial direction, whereupon one contact 34 breaks from the adjacent contact 36 and the other contact 34 makes with its contact 36, whereby to perform a switching function at each end of the reciprocatory path of movement of the armature.

At its inner end, in the embodiment of the invention herein disclosed, each contact 36 is connected to the pigtail of a conductive brush 38 which is spring-pressed radially outwardly at right angles to the plane of the contacts 34 and 36. The circumferential spacing of the brushes 38 from the contacts 34 may, of course, be varied as desired, but it is preferred that the two brushes lie in a common plane spaced circumferentially from both sets of contacts. At their outer ends, the brushes 38 project into a longitudinal groove 40 in the periphery of the armature which groove extends throughout the full length of the armature. The groove is intended for reception therein of a longitudinal guide block 42 which is secured to the inner wall of the cylinder and extends from adjacent one end to adjacent the other end thereof for the purpose of slidably guiding the armature and retaining the same against rotation, whereby the armature will be retained in the position wherein its contacts 34 are aligned with the contacts 20*a*–20*b* and 22*a*–22*b*. The guide block 42 may suitably be formed of a plastic insulating material having a low coefficient of friction, for the same purposes as previously explained. (In non-circular cylinder configurations, the guide block would not be necessary, since the configuration of the cylinder and armature would prevent rotation of the armature.)

Fixedly mounted on the guide block 42 is an elongate conductor bar 44 which extends into the groove 40 and is slidably engaged by the brushes 38 throughout the reciprocatory path of movement of the armature. The bar 44 in turn is adapted to be connected by way of conductive bolts 46 and a tap or lead 48 to the side of the power supply opposite that to which the taps or leads 18 are connected.

The cylinder 10, coils 12, armature 14, abutments 16, stationary contacts 20*a*–20*b* and 22*a*–22*b*, and longitudinally shiftable contacts 34, are, of course, properly correlated to one another to achieve the intended purposes. While the necessary correlation will be obvious to those skilled in the art, I will describe, by way of example, the correlation employed in the preferred embodiment of the invention. As shown, the coils 12 are spaced apart equal distances from one another and from the abutments 16, and the stationary contacts are centered in such spaces, i.e., the contact 20*a* is positioned centrally in the space between the left-hand abutment 16 and the left-hand coil 12*a*, the contacts 20*b* and 22*a* are positioned centrally of the space between the two coils and the contact 22*b* is positioned centrally in the space between the right-hand coil 12*b* and the right-hand abutment 16. If more than two coils were provided, their spacing and contact arrangements would be the same as that between the two coils illustrated. The cylinder 10 is, of course, of a length to accommodate the aforesaid relationship of the coils 12, the abutments 16 and the contacts 20*a*–20*b* and 22*a*–22*b*.

The armature 10 is of a length less than twice, preferably substantially less than twice, the spacing of the centers of the coils 12*a* and 12*b* from the abutments 16 adjacent thereto, and yet of a length to accommodate, with freedom for sliding movement, contacts 34 that are of a length only slightly less than the spacing between the contacts of each set mounted on the cylinder, e.g., the spacing between the contacts 20*a* and 20*b*. The contacts 34 in turn are so positioned (preferably centered) on the armature that the distance between the trailing end of the contact 34 and the center of the armature is less than the distance between the center of the coil and its contacts.

With the defined structural arrangement, and with the armature positioned as shown in FIGURE 1 and the two power supply leads 18 and 48 connected to opposite sides of a suitable power source, either A.C. or D.C., the operation of the motor is as follows: The left-hand coil 12*a* is initially energized by virtue of current flow via the lead 48, the bar 44, the left-hand brush 38 and contact 36, the lower slidable contact 34, the contact 20*a*, the tap 20, the windings of the coil and the lead 18. The coil 12*a* thus produces a magnetic field, causing the armature 14 to move to the right toward a centered position relative to the coil 12*a*. However, shortly before the armature reaches such centered position, the lower contact 34 disengages from the contact 20*a* whereby the coil 12*a* is de-energized and the momentum of the armature causes it to slide by the coil 12*a* until the lead end of the

lower contact 34 engages the contact 20*b* of the coil 12*b*. The coil 12*b* thus becomes energized and exerts a magnetic attraction for the armature, so that the armature (the lead end of which is now in the field of influence of coil 12*b*) is drawn to the right toward a centered position relative to the coil 12*b*. Again, however, the lower contact 34 disengages from the contact 20*b* so that the armature, due to its momentum, slides past the coil 12*b* toward the right-hand abutment 16. During this movement, the upper contact 34 and the contacts 22*a* and 22*b* are ineffective since the upper contact 34 is not engaged with and thus is not energized via the upper right-hand supply contact 36.

When the right-hand end of the armature 14 engages the right-hand abutment 16, the armature is abruptly stopped. However, the contact bars 34 due to their momentum continue to move to the right, whereby the lower left-hand switch means 34–36 is opened and the upper right-hand switch means 34–36 is closed, as shown in FIGURE 2. Thus, the lower contacts 20*a*, 20*b* and 34 are rendered ineffective but the circuit is now closed via the upper contacts 34 and 22*b* through the coil 12*b*, again to energize this coil. Consequently, the coil 12*b* again exerts a centering force relative to the armature, now causing the armature (which has glided past center position) to move toward the left. Before centered position is reached, the upper contact 34 breaks from the contact 22*b* whereby the armature slides past the coil 12*b* until the upper contact 34 engages the contact 22*a* to energize coil 12*a* and pull the armature further to the left. Before the armature reaches center position relative to the coil 12*a*, the upper contact 34 disengages from the contact 22*a* whereupon the center of the armature moves past the center of the coil 12*a*. When the armature strikes the left-hand abutment 16, the impact or momentum responsive contact bars 34 shift to the left, whereby the apparatus is reconditioned, as shown in FIGURE 1, for the cycle of operation above described.

From the foregoing, it will be obvious to those skilled in the art that the motor of the present invention may be comprised of substantially any desired number of armature actuating coils, even a single coil disposed substantially centrally of a relatively short cylinder 10.

The present invention is thus seen to provide an extremely economical and compact universal electromagnetic reciprocating motor. The motor may be fabricated in substantially any size, for substantially any horsepower output and/or for substantially any reciprocatory stroke and speed. For example, the motor may be made of about hand size for operation of portable reciprocating power tools, such as saber saws. Accordingly, the objects and advantages of the invention have been shown herein to be attained in a convenient, economical and practical manner.

While I have shown and described what I regard to be the preferred embodiment of my invention, it will be appreciated that various changes, rearrangements and modifications may be made therein without departing from the scope of the invention, as defined by the appended claims.

I claim:

1. An electromagnetic reciprocating motor comprising a non-magnetic cylinder having abutments adjacent its ends, a plurality of electric coils arrayed in longitudinally spaced relation to one another along said cylinder, each coil being connected to one side of an electric power source and including a pair of contacts extending through said cylinder in circumferentially spaced relation to one another, corresponding contacts of the coils defining two sets of longitudinally spaced contacts, a magnetic armature slidably mounted in said cylinder, switch means on said armature responsive to engagement of the armature with said abutments and including a pair of alternately energized contacts circumferentially spaced from one another and respectively engageable with the contacts of said two sets, a power supply element extending from adjacent one end to adjacent the other end of said cylinder and connected to the other side of the electric power source, and conductor means connecting said supply element to said switch means.

2. An electromagnetic reciprocating motor comprising a non-magnetic cylinder having abutments adjacent its ends, at least one electric coil mounted on said cylinder in spaced relation to its ends, said coil being connected to one side of an electric power source, a pair of contacts connected to said coil and extending through said cylinder in circumferentially spaced relation to one another, a magnetic armature slidably but non-rotatably mounted in said cylinder, switch means on said armature responsive to engagement of the armature with said abutments and including a pair of alternately energized contacts circumferentially spaced from one another and aligned respectively with said coil contacts, a power supply bar extending longitudinally of said cylinder and connected to the other side of the electric power source, and conductor means on said armature connected to said switch means and slidably engaging said bar for supply of electric power alternately to the contacts on said armature.

3. An electromagnetic reciprocating motor comprising a non-magnetic cylinder having abutment means adjacent its ends, at least one electric coil on said cylinder adjacent but spaced from one of its ends, said coil being connected to one side of an electric power supply and including a pair of contacts projecting through said cylinder in circumferentially spaced relation to one another, a magnetic armature reciprocably mounted in said cylinder, switch means on said armature responsive to engagement of the armature with said abutments and including a pair of alternately energized circumferentially spaced contacts on the surface of the armature engageable respectively with said coil contacts, a power supply bar extending from adjacent one end to adjacent the other end of said cylinder and connected to the other side of the electric power supply, and conductor means on said armature slidably engaging said bar and connected to said switch means for alternate energization of the contacts on said armature, said switch means upon engagement of said armature with the abutment at the one end of said cylinder coupling one armature contact with said bar and de-energizing the other armature contact, said armature being of a length less than twice the spacing between the center of said coil and the adjacent end of the cylinder, said one armature contact being aligned with and engaging one contact of said coil when the armature is in said one end of said cylinder for energizing said coil to initiate movement of said armature toward the other end of said cylinder, said one armature contact and said one coil contact having a contact length sufficient to maintain said coil energized until the center of the armature approaches but has not reached the center of said coil.

4. An electromagnetic reciprocating motor as set forth in claim 3, including a plurality of coils arrayed in longitudinally spaced relation along said cylinder, each coil being connected to one side of the electric power supply and including a pair of contacts projecting into said cylinder and aligned in respective sets with the contacts of the first-named coil, the contact of each succeeding coil in the direction of armature movement corresponding to said one contact of the first-named coil being spaced from said one contact of the preceding coil a sufficient distance that said one armature contact disengages from said one contact of the preceding coil before engaging the one contact of the next succeeding coil, said one armature contact and said one contact of each succeeding coil having a contact length sufficient to maintain the respective succeeding coil energized from substantially the time the leading end of said armature enters the field of influence of said succeeding coil until the center of the armature approaches but has not reached the center of the succeed-

ing coil, said other armature contact being aligned with and engaging the other contact of the coil adjacent said other end of said cylinder when the armature is in said other end of said cylinder and has engaged the abutment at said other end of said cylinder for energizing the last-named coil to initiate movement of said armature toward said one end of said cylinder, said other armature contact, said other contact of said last-named coil and the other contacts of the succeeding coils in the direction from said other end of said cylinder toward said one end of said cylinder having the same relationship to one another as have said one armature contact, said one contact of said first-named coil and said one contact of the succeeding coils in the direction from said one end of said cylinder toward said other end of said cylinder.

5. An electromagnetic reciprocating motor comprising a non-magnetic cylinder having abutments adjacent its ends, a plurality of electric coils arrayed in longitudinally spaced relation to one another along said cylinder, each coil being connected to one side of an electric power supply and including a pair of contacts extending through said cylinder in circumferentially spaced relation to one another to opposite sides of the respective coil, corresponding contacts of the coils defining two sets of longitudinally spaced contacts, a magnetic armature reciprocably mounted in said cylinder, switch means on said armature responsive to engagement of the armature with said abutments and including a pair of circumferentially spaced alternately energized elongated contacts of a length less than the spacing between the contacts of each of said sets and respectively engageable sequentially with the contacts of the two sets, and means connecting said switch means to the other side of the electric power supply.

6. An electromagnetic reciprocating motor comprising a non-magnetic cylinder having abutments adjacent its ends, a plurality of electric coils arrayed in longitudinally spaced relation to one another along said cylinder, each coil being connected to one side of an electric power supply and including a pair of contacts extending through said cylinder in circumferentially spaced relation to one another to opposite sides of the respective coil, corresponding contacts of the coils defining two sets of longitudinally spaced contacts, a magnetic armature reciprocably mounted in said cylinder, switch means on said armature responsive to engagement of the armature with said abutments and including a pair of circumferentially spaced alternately energized elongated contacts of a length less than the spacing between the contacts of each of said sets and respectively engageable sequentially with the contacts of the two sets, a power supply element extending from adjacent one end to adjacent the other end of said cylinder and connected to the other side of the electric power supply, and conductor means connecting said element to said switch means.

7. An electromagnetic reciprocating motor comprising a non-magnetic cylinder having internal abutments adjacent its ends, a plurality of electric coils surrounding said cylinder in equally spaced relation to one another, each coil being connected to one side of an electric power supply and including a pair of contacts extending through said cylinder in circumferentially spaced relation to one another to opposite sides of the respective coil, corresponding contacts of the coils being aligned with one another longitudinally of said cylinder and defining two sets of equally spaced contacts, a magnetic armature reciprocably but non-rotatably mounted in said cylinder between said abutments, switch means on said armature responsive to engagement of the armature with said abutments and including a pair of circumferentially spaced alternately energized contacts respectively aligned and engageable sequentially with the contacts of the two sets, the contacts on the armature being elongated but of a length less than the spacing between the contacts of each set, and means connecting said switch means to the other side of the electric power supply.

8. An electromagnetic reciprocating motor comprising a non-magnetic cylinder having internal abutments adjacent its ends, a plurality of electric coils surrounding said cylinder in equally spaced relation to one another, each coil being connected to one side of an electric power supply and including a pair of contacts extending through said cylinder in circumferentially spaced relation to one another to opposite sides of the respective coil, corresponding contacts being aligned with one another longitudinally of said cylinder and defining two sets of equally spaced contacts, a magnetic armature reciprocably mounted in said cylinder between said abutments, switch means on said armature responsive to engagement of the armature with said abutments and including a pair of circumferentially spaced alternately energized contacts respectively aligned and engageable sequentially with the contacts of the two sets, the contacts on the armature being elongated but of a length less than the spacing between the contacts of each set, a power supply bar on the internal wall of said cylinder extending longitudinally from adjacent one end to adjacent the other end of said cylinder and connected to the other side of the electric power supply, a longitudinal groove in said armature spaced circumferentially from the contacts thereon and slidably engaging said bar for retaining said armature against rotation, and brush means in said groove slidably engaging said bar and connected to said switch means.

9. An electromagnetic reciprocating motor comprising a non-magnetic cylinder having abutments adjacent its ends, at least one electric coil on said cylinder, said coil being connected to one side of an electric power supply and including a pair of contacts extending through said cylinder in circumferentially spaced relation to one another to opposite sides of the coil, a magnetic armature reciprocably mounted in said cylinder, switch means on said armature comprising a pair of elongate contacts slidably mounted on said armature in circumferentially spaced relation to one another for engagement respectively with the contacts of said coil, a fixed contact on said armature adjacent one end of one of said elongate contacts and a fixed contact on said armature adjacent the other end of the other of said elongate contacts, said elongate contacts being of significant mass for movement relative to said armature upon impact of the armature against said abutments for performing switching functions relative to said fixed contacts, and means connecting said fixed contacts to the other side of the electric power supply.

10. An electromagnetic reciprocating motor comprising a non-magnetic cylinder having abutments adjacent its ends, at least one electric coil on said cylinder, said coil being connected to one side of an electric power supply and including a pair of contacts extending through said cylinder in circumferentially spaced relation to one another to opposite sides of the coil, a magnetic armature reciprocably mounted in said cylinder, said armature having a pair of circumferentially spaced longitudinally extending grooves in its side wall respectively aligned with the contacts of said coil, a contact fixed in one end of one groove and a contact fixed in the other end of the other groove, a pair of elongate contacts of significant mass slidably mounted in said groves for movement into and out of engagement with the respective fixed contacts upon impact of said armature against said abutments, leads from said fixed contacts extending radially into the interior of said armature, brush means connected to said leads and extending to a radially exposed portion of the armature spaced circumferentially from said grooves, and a power supply bar extending longitudinally of said cylinder for slidable engagement by said brush means, said bar being connected to the other side of the electric power supply.

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ORIS L. RADER, *Primary Examiner.*