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H. F. KREBS
DIRECT CURRENT TO ALTERNATING CURRENT
ADAPTER FOR ROTARY SOLENOID

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2 Sheets-Sheet 1

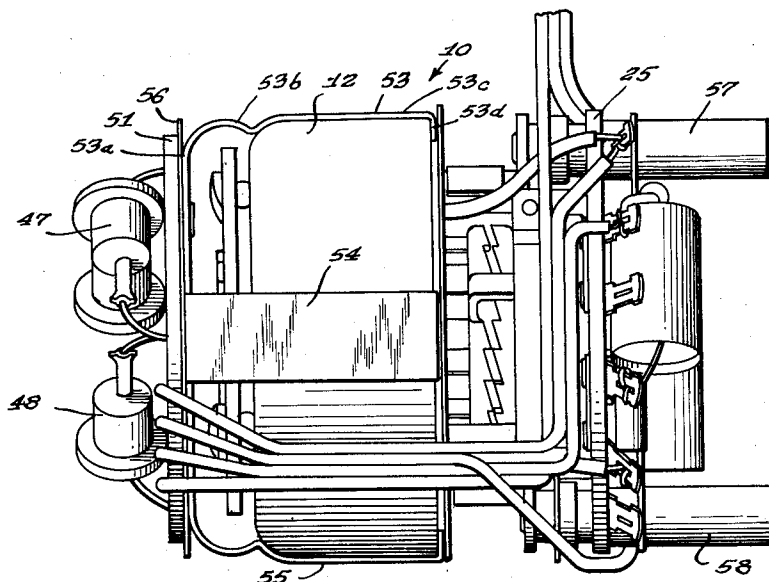


FIG. 1

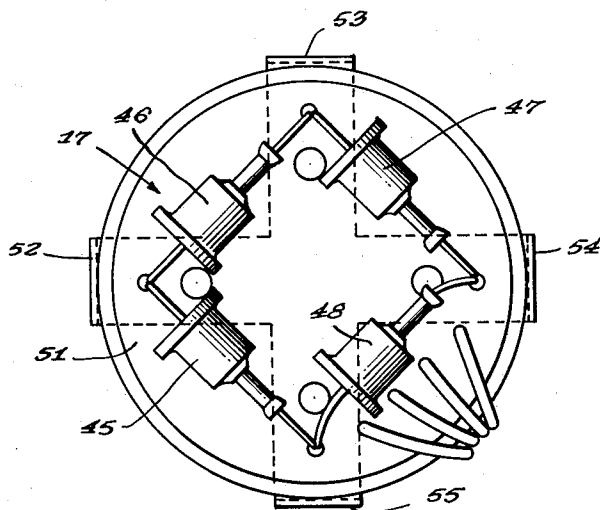


FIG. 2

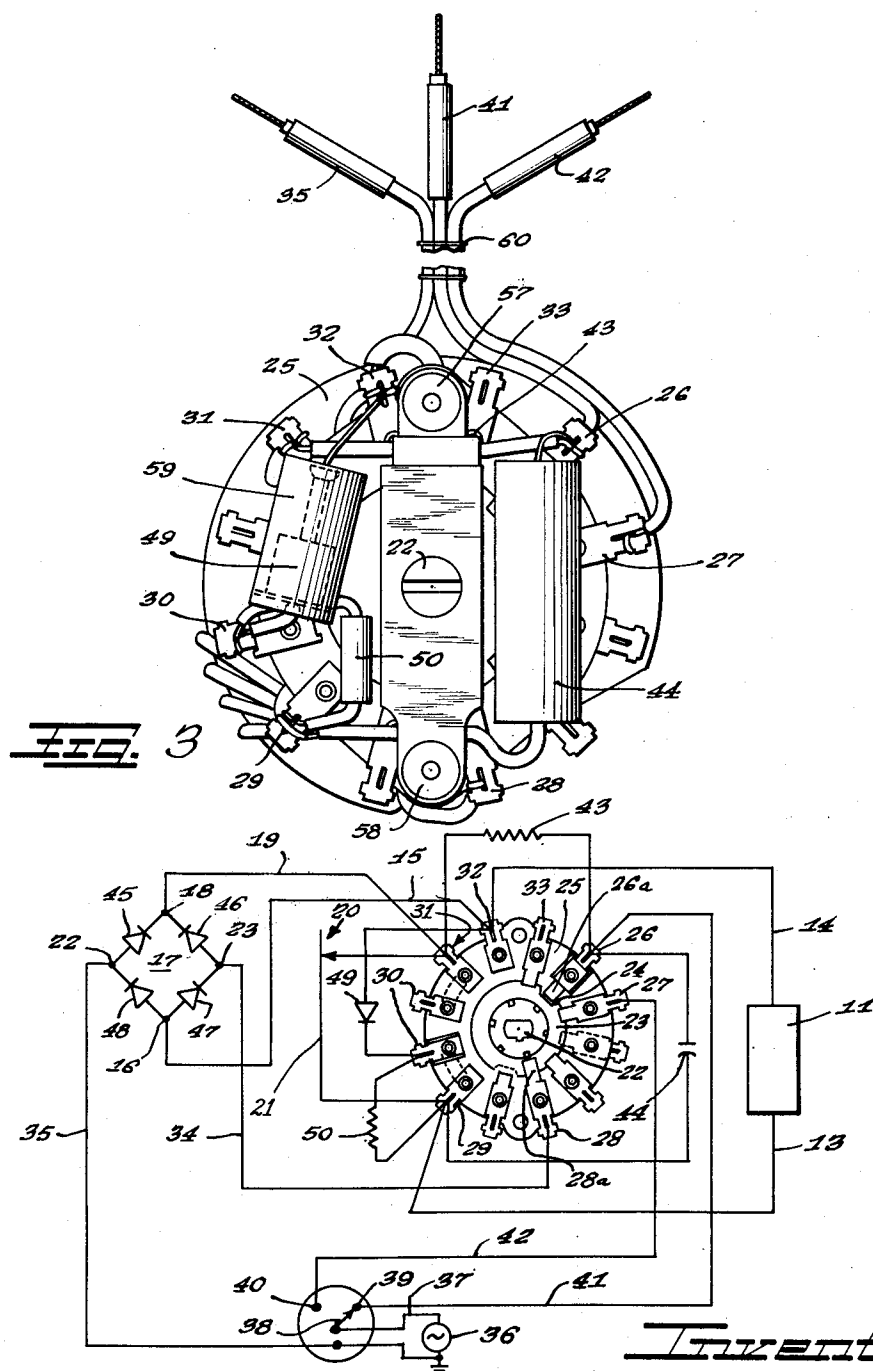
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DIRECT CURRENT TO ALTERNATING CURRENT ADAPTER FOR ROTARY SOLENOID

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This invention relates to a solenoid driven step-by-step actuating mechanism of the type used with a rotary coaxial switch. More particularly, this invention relates to such a mechanism including a direct current actuated solenoid and apparatus integral therewith for adapting such a solenoid for actuation by either direct or alternating-current voltage.

Rotary coaxial switches of the type with which the present invention may suitably be used are shown for example in U.S. Patent No. 2,733,318, issued to G. E. Jacques et al. on January 31, 1956, or in U.S. Patent No. 2,766,355, issued to D. D. Cherry on October 9, 1956. Various types of step-by-step actuating mechanisms for such switches are known and typical exemplary mechanisms are for example described in U.S. Patent No. 2,576,609, issued to A. J. Kreiner on November 27, 1951, or in U.S. Patent No. 2,786,153, issued to R. L. Gates, on March 19, 1957. In commercial and military practice, such switches have in the past, been actuated by a mechanism commonly driven by a solenoid requiring the application of a unidirectional or direct-current voltage. In many applications such a unidirectional voltage is not readily available. Thus, in aircraft, missiles, and portable or fixed ground base equipment, alternating current of various frequencies is more commonly found than direct or unidirectional current. One prior art solution to this problem has been to use an alternating current motor as the switch actuating element. Such motors, however, are extremely bulky and heavy by comparison with a relatively simple D.-C. rotary solenoid. Another solution, of course, is to incorporate a source of unidirectional current or voltage in the aircraft, missile, or other equipment in which the switch may be used. This also leads, however, to the addition of relatively heavy, bulky and expensive equipment and to modification of an entire system simply to provide operating power to a relatively small number of such switches.

It is therefore, an object of this invention to provide a rotary switch actuating mechanism which itself includes a rectifier conversion unit permitting a direct current solenoid to be operated from either direct or alternating current voltages.

It is a further object of this invention to provide a compact, light-weight, snap-on adapter or conversion unit which may be integrally combined with existing D.-C. rotary solenoid units to adapt such units for operation from either direct or alternating current supplies with a minimum increase in cost, weight, and complexity.

It is a feature of this invention to provide a printed circuit board having with solid state rectifiers connected thereon in a full wave bridge rectifier circuit and further having brackets by which the conversion unit may be readily attached to solenoid or switch housings. It is a further feature of this invention to provide circuitry for preventing excessive back voltages from appearing across such a bridge circuit due to the inductive kick of the solenoid when actuated.

While the novel and distinctive features of the invention are particularly pointed out in the appended claims, a more expository treatment of the invention in principle and in detail, together with additional objects and advantages thereof, is afforded by the following description

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and accompanying drawings in which like reference characters are used to refer to like parts throughout and wherein:

FIGURE 1 is a side elevational view of the A.-C., D.-C. solenoid switch actuating assembly of the present invention.

FIGURE 2 is an end elevational view of the apparatus of FIGURE 1 showing the snap-on rectifier assembly in plan.

FIGURE 3 is an end elevational view of the other end of the assembly shown in FIGURE 1.

FIGURE 4 is a schematic circuit diagram of the apparatus shown in FIGURE 1.

Turning now to the drawings, there is shown a solenoid assembly 10 which may, for example, be generally of the type described in detail in the above noted U.S. Patent No. 2,576,609 to A. J. Kreiner. The solenoid 11 shown in FIGURE 4, would of course, be mounted within the housing 12 of assembly 10 seen in FIGURE 1. Solenoid 11 is actuated through a circuit including leads 13 and 14. Lead 14 is in turn connected by a lead 15 to a first output terminal 16 of a full wave bridge rectifier circuit 17. The second output terminal 18 of bridge 17 is connected by lead 19 through an interruptor 20 and back through lead 13 to the other side of the solenoid.

As long as an alternating current voltage is applied between the input terminals 22 and 23 of bridge 17, there will be a unidirectional or direct current voltage appearing between output terminal 16 and 18 of the bridge which will thus repeatedly actuate the solenoid 10 as the interruptor 20 makes and breaks its circuit in a manner well-known in the art.

As the interruptor 20 makes and breaks the circuit of solenoid 11, the solenoid actuates an output shaft 22 in incremental or step-by-step rotation, the shaft rotating by a predetermined amount for each actuation of the solenoid in a manner more fully set forth in the above identified Kreiner patent. An annular conducting ring 23 is rigidly attached to shaft 22 and rotates therewith. Conducting ring 23 is composed of any suitable electrically conductive material and is suitably insulated from shaft 22 in any conventional manner. Ring 23 is provided at its outer periphery with a recess 24. On an annular insulating support member 25 surrounding ring 23 and shaft 22, there are mounted a plurality of contact members such as the contacts 26, 27, 28, 29, 30, 31, and 32. Each of these contacts, and as many other similar contacts as may be desired for a purpose which will become apparent below, may include a tie point for the various leads of the circuit and means such as a rivet to attach the contact to supporting member 25. Additionally, contacts such as shown at 26, 27, and 33 are also provided with contact fingers extending out to slidably engage the annular conducting ring 23 as shown in FIGURE 4. It will be noted that each of these contact fingers extends radially into ring 23 for a distance less than the depth of the recess 24. Furthermore, recess 24 is of a width greater than the width of these contact fingers so that when the ring 23 has been rotated, to any given position in which the recess 24 is aligned with the underside of the contact fingers (such as the contact finger 26a of contact 26 shown, by way of example, in FIGURE 4) there will be no connection between the ring and the contact finger above the recess.

It will further be noted that one contact, shown in FIGURE 4 as contact 28, has a contact finger 28a which extends radially into the conductor ring 23 for a distance greater than the depth of recess 24 so that this particular contact is always in closed circuit relationship with conducting ring 23. Contact 28 and its elongated

finger 28a may be designated a common contact and is directly connected over line 34 to one of the input terminals 23 of the bridge circuit 17.

The other input terminal 22 of bridge 17 is connected by a line 35 to one side of a source 36 of alternating current voltage which may conveniently be the grounded side of source 36. The other side of source 36 is connected by a conductor 37 to a switch arm 38 which may have any desired number of contact positions. By way of example, this is shown in FIGURE 4 as a two position switch in which arm 38 may contact either terminal 39, as shown, or terminal 40. Of course, it will be understood that any equivalent arrangement such as a plural inlet receptacle may be used in place of switch arm 38. The positioning of switch arm 38 selects the position to which the rotary solenoid actuator will rotate the shaft and thereby determining the position to which the rotary coaxial switch or other operated member will be turned. While the circuit of FIGURE 4 illustrates a two-position switch by way of example, it will be apparent to those skilled in the art that any desired number of positions may be provided for by mere duplication of the circuit shown.

Terminal 39 is connected by lead 41 to contact member 26 bottom side, the contact finger 26a of which is shown positioned over the recess 24 in ring conductor 23. In the position shown, it will be apparent that the solenoid has been operated to position the ring conductor recess and thereby the output shaft in the position determined by the connection of the circuitry through switch arm 38 to contact 26. Switch contact 40 on the other hand, is connected by lead 42 to contact member 27. If switch arm 38 is thrown from terminal 39 to terminal 40, a circuit will be completed from the A.-C. source 36 through switch arm 38, contact 40, lead 42, contact 27, conductor ring 23, common contact 28, and lead 34 to one input terminal 23 of bridge circuit 17. The other input terminal 22 of bridge circuit 17 is, as noted above, directly connected by lead 35 to the other side of source 36. The bridge circuit is therefore actuated and its output terminals 16 and 18 will apply a unidirectional voltage to the solenoid 11 over the circuit discussed above and including conductor 19, interruptor 20, conductor 13, solenoid 11, conductor 14, conductor 15 and bridge terminal 16. The solenoid will then be actuated in step-by-step fashion under the control of interruptor 20 to rotate the conductive ring 23 until recess 24 is positioned under contact 27, thereby breaking the supply circuit to bridge 17.

In order to prevent arcing across the contacts of the interruptor 20 when its contacts make and break, a resistor 43 and a capacitor 44 are connected in series with each other and in parallel with the interrupter through leads connected as shown in FIGURE 4 to any of the tie points provided by unused contact members or by any other convenient means.

In order to reduce space and weight requirements, it is desirable that the diodes 45, 46, 47, and 48 which are connected as shown in FIGURE 4 to form the bridge circuit 17 should be of the solid state type and are preferably silicon diodes which in one exemplary embodiment of the invention were type 1N539 diodes. It will be appreciated, however, that when the circuit is opened and closed by the interrupter, a solenoid of suitable rating for use as the solenoid 11 will generate a substantial inductive kick which, in the above noted exemplary embodiment of the invention, was found to produce a peak inverse voltage across terminals 16 and 18 of the bridge circuit 17 of as high as 850 volts. In order to reduce this peak inverse voltage appearing across the bridge so as to permit the use of relatively small rectifiers, a shorting path across the coil is provided at the time the circuit is broken. This shorting path includes rectifier 49 and a series connected resistor 50. Rectifier 49, it will be noted, is connected on one side to contact

32 which in turn is directly connected by lead 14 to solenoid 11. The other side of rectifier 49 is connected to contact 30 as is resistor 50. The other end of resistor 50 is in turn connected to contact 29 which is directly connected by lead 13 to the other side of solenoid 11. In the above noted exemplary embodiment of the invention, the rectifier 49 may conveniently be a type 1N538 rectifier, whereas resistor 50 may conveniently be a 1000 ohm $\frac{1}{2}$ watt resistor. The resistor 50 is included in the circuit to limit the circulating currents in the shorting shunt path since excessive current would increase the actuation time of the switch. It will be noted that the diode 49 has a polarity with respect to contact 32 (and hence, solenoid 11) which is the opposite of that of the diodes 45 and 46 of bridge 17 with respect to terminals 18 and contact 32. Thus, the peak inverse voltage between bridge terminals 18 and 16 is reduced by the shunting current flow through diode 49 and limiting resistor 50. This in turn makes possible the use of relatively small light-weight rectifiers of the solid state type, such as the silicon rectifiers 45, 46, 47 and 48, which may conveniently be mounted upon a printed circuit board 51 as shown in FIGURE 2. As shown in FIGURES 1 and 2, printed circuit board 51 has attached thereto by rivets or any other convenient means, four bracket arms 52, 53, 54 and 55. A piece of fish paper or other insulating material 56 may be interposed between the printed circuit board 51 and the bracket arms. Each of the bracket arms is of the same shape and comprises a first straight portion such as the straight portion 53a of bracket 53, a second generally S-shaped portion such as the portion 53b of bracket 53 which extends away from portion 53a in a generally perpendicular or right angle relationship, and a third generally L-shaped portion 53c which continues straight away from portion 53b. As may be seen in FIGURE 1, the end 53d of L portion 53c is adapted to snap over the end of the housing 12 of solenoid assembly 10 whereas the S-shaped portion 53b by spring action holds the printed circuit board 51 in firm spaced relationship to the other end of housing 12.

The annular insulating member 25 and the switch assembly thereon may be mounted to members protruding from the other end of housing 12 as by bolts 57 and 58 or in any other convenient manner. It will be noted from FIGURE 3 that the shunting diode 49 may conveniently be mounted upon insulating member 25 in a suitable glass or other insulating sleeve 59. Similarly, resistor 50, in series with diode 49, may conveniently be connected between tie points 30 and 29. In like fashion, the arc suppressing series resistor 43 and capacitor 44 may also be mounted between tie points 31, 26, and 29, as shown in FIGURES 3 and 4. Line 35 from terminal 22 of the bridge circuit which is adapted to be connected to the grounded side of A.-C. source 36, as well as lines 41 and 42 which are connected to the actuating contacts of the switch assembly may conveniently be laced together by lacing 60 and brought out to suitable pins which may be used to make contact with terminals such as 39 and 40 indicated in FIGURE 4 as forming part of any suitable receptacle or switching device.

It should of course, be understood that although the full wave bridge rectifier circuit assembly 17 has been illustrated as mounted on an annular or circular printed circuit board, which may be attached by snap-on brackets to existing solenoid actuator housings with the appropriate shunting circuit diode being included in the switch circuit as a modification of existing equipment, it is also contemplated that the circuit board 17 and its associated components could be rigidly or integrally formed as a portion of the solenoid housing 12. Such an integral construction may be preferred in the manufacture of entirely new units. In either the snap-on or the integral type of construction any suitable type cover may, of course, also be included to enclose the full wave bridge rectifier circuit.

It will thus be seen that I have provided a rotary solenoid actuator which may be operated from 115 volts D.-C. or 115 volts A.-C. at all frequencies between 50 cycles and 100 kilocycles. In the exemplary embodiment noted above, the unit drew 1.9 amperes peak and 0.9 ampere average current for the intermittent duty cycle in which the rotary solenoid was energized only during switching. The unit has been found to function satisfactorily over a temperature range of -65° F. to 165° F. and is highly resistant to shock, vibration, and humidity. The fact that the unit can be operated from direct current or from alternating current over a range of 50 cycles to 100 kilocycles permits a single model of switch actuator to be used either for standard commercial power or for the A.-C. found in aircraft, missiles, and portable or fixed ground base equipment. It is truly a universal 115 volt actuated coaxial switch.

While the principles of the invention have now been made clear, there will be immediately obvious to those skilled in the art many modification in structure, arrangement, proportions, the elements and components used in the practice of the invention and otherwise, which are particularly adapted for specific environments and operating requirements without departing from those principles. The appended claims are therefore intended to cover and embrace any such modification within the limits only, of the true spirit of the invention.

I claim as my invention:

1. For attachment on the two axial ends of a rotary unit switching device having a step-by-step rotary solenoid adjacent one axial end thereof and actuating a directly connected and coaxial multi-position rotating switch adjacent its other end to permit its operation on alternating as well as on direct current; a full wave rectifier attachment comprising an insulating disk having means forming a full wave bridge rectifier circuit including four solid state diode rectifiers mounted on its outer face, peak inverse voltage reducing means for the voltage across said bridge circuit including a fifth rectifier and a series connected resistor, wires connecting said bridge circuit and said voltage reducing means and adapted to interconnect them with a power source and such a rotary solenoid, means to detachably secure said disk coaxially on the axial end of such a rotary unit and its rotary solenoid comprising axially extending and spaced springy arms secured on the other and inner face of said disk to securingly embrace an axial end of such a rotary solenoid, and means to secure said voltage reducing means on the other end of such a rotary switch device on its rotary switch.

2. For attachment on the two axial ends of a rotary unit switching device having a step-by-step rotary solenoid adjacent one axial end thereof and actuating a directly connected and coaxial multi-position rotating switch adjacent its other end to permit its operation on alternating

as well as on direct current; attachment means comprising a disk having inner and outer faces, a full wave bridge rectifier circuit means mounted on its outer face, peak inverse voltage reducing means for the voltage across said bridge circuit, means connecting said bridge circuit and said voltage reducing means and adapted to interconnect them with a power source and such a rotary solenoid, means to detachably secure said disk coaxially on the axial end of such a rotary unit and its rotary solenoid comprising axially extending and attachably engaging arm means secured on the other and inner face of said disk to detachably secure to the outer axial end of such a rotary solenoid, and means to secure said voltage reducing means on the other end of such a rotary switching device on its rotary switch.

3. For attachment on the two axial ends of a rotary unit switching device having a step-by-step rotary solenoid adjacent one axial end thereof and actuating a directly connected and coaxial multi-position rotating switch adjacent its other end to permit its operation on alternating as well as on direct current; a full wave rectifier attachment comprising an insulating disk having means forming a full wave bridge rectifier on its outer face and detachably securing means on its other face to engage said rotary solenoid and axially position said disk and also comprising a second insulating disk carrying on its outer face means to reduce the peak inverse voltage across said bridge circuit and including an additional rectifier and a series connected resistor, said second insulating disk having means to detachably secure it on the other axial end of said rotary unit and on its rotary switch, said securing means acting between said rotary switch and said second insulating disk and means to detachably and electrically connect said bridge circuit, said voltage reducing means, a suitable power source and such a rotary solenoid.

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