

Aug. 7, 1951

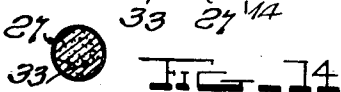
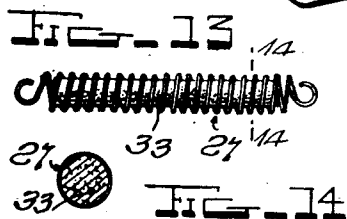
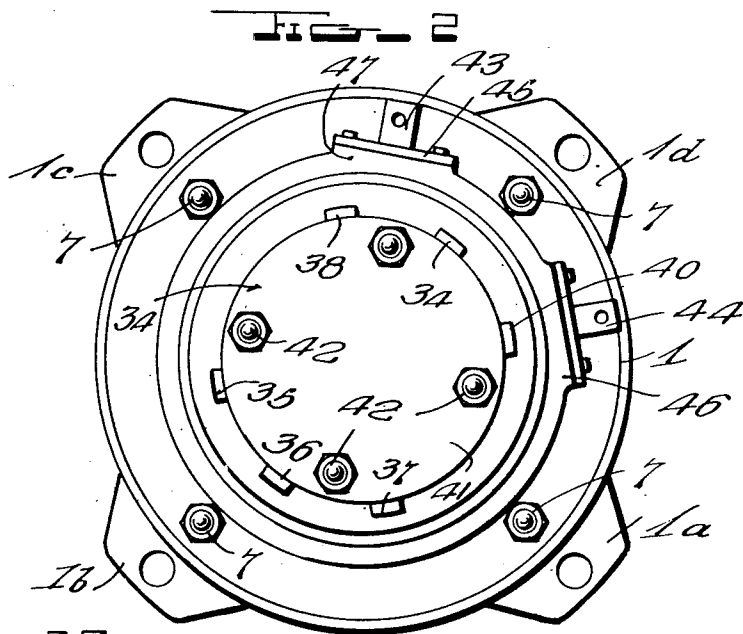
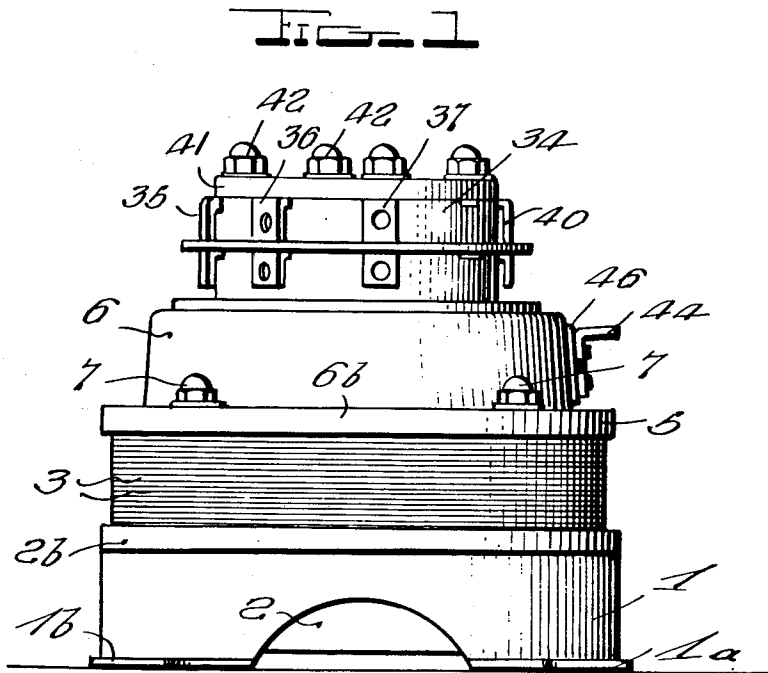
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2,563,271

ALTERNATING CURRENT ACTUATOR OR RELAY

Filed June 1, 1948

3 Sheets-Sheet 1



INVENTOR.
Osborne I. Price,
BY
John B. Grady
ATTORNEY

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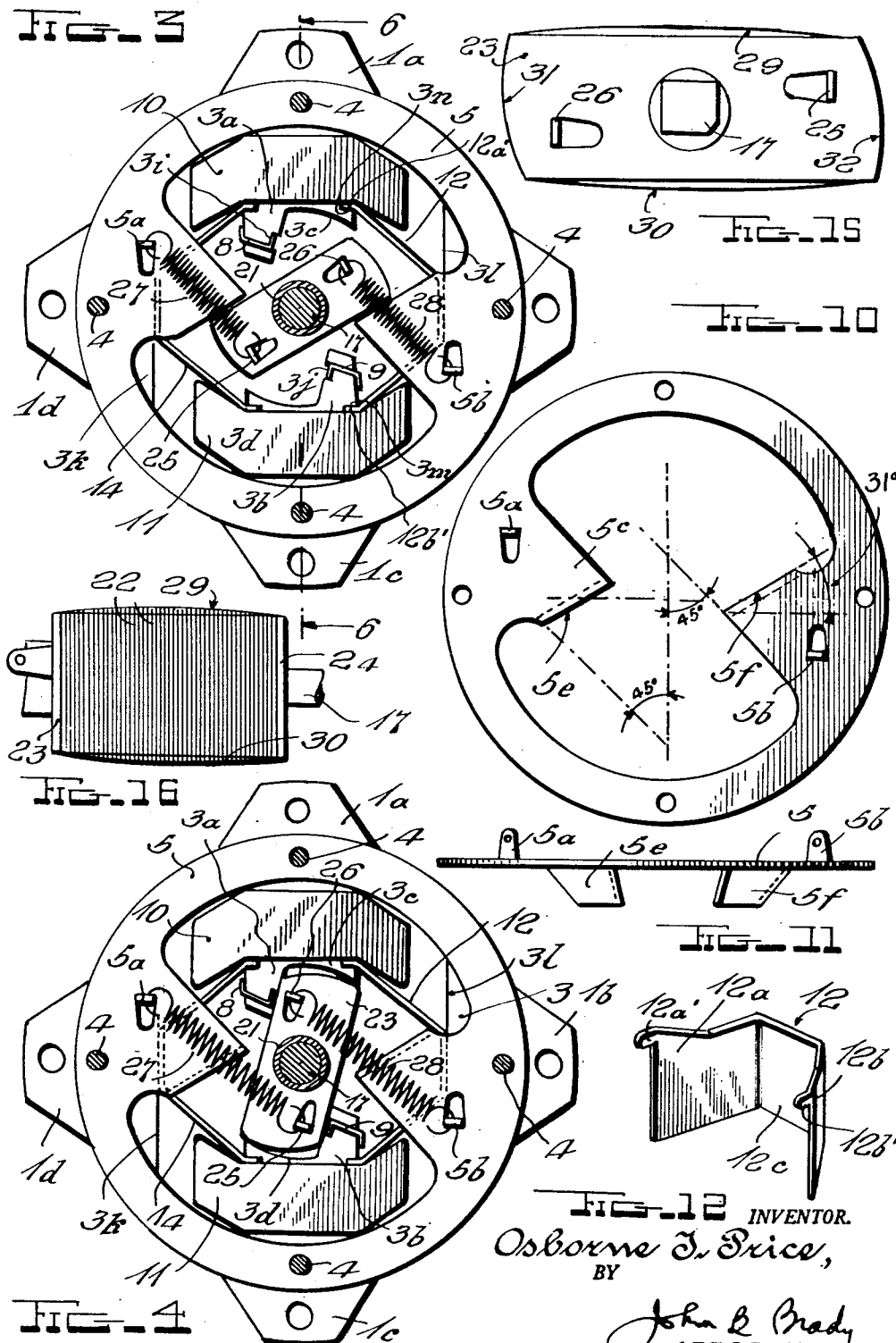
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ALTERNATING CURRENT ACTUATOR OR RELAY

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FIG. 3



INVENTOR.
Osborne I. Price,
BY

John E. Brady
ATTORNEY

Aug. 7, 1951

O. I. PRICE

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3 Sheets-Sheet 3

FIG. 5

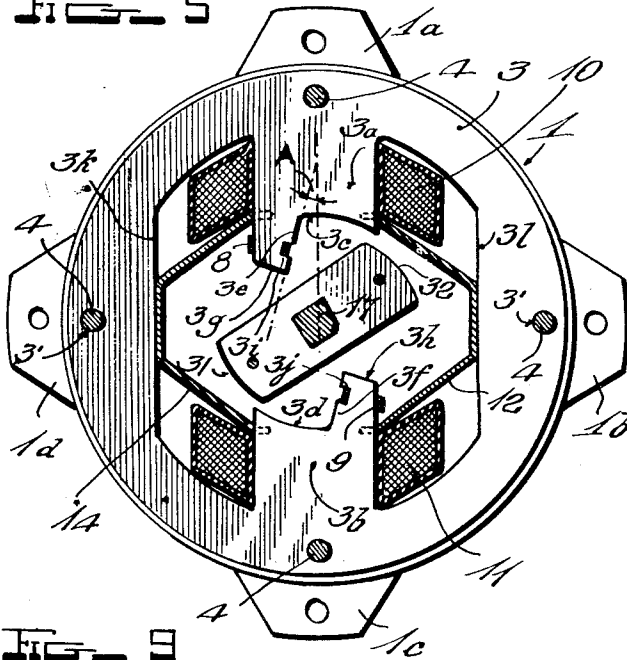


FIG. 7

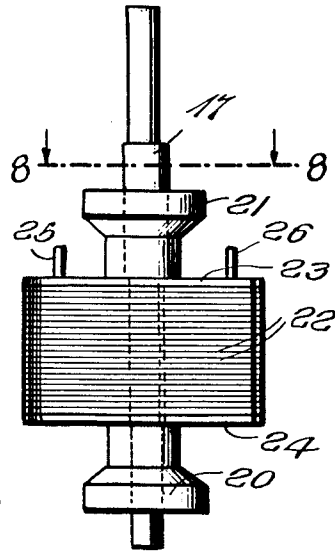


FIG. 9

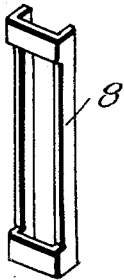
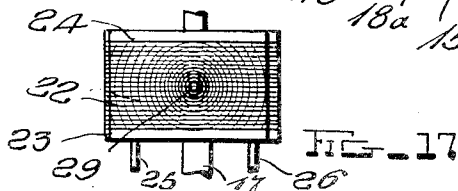
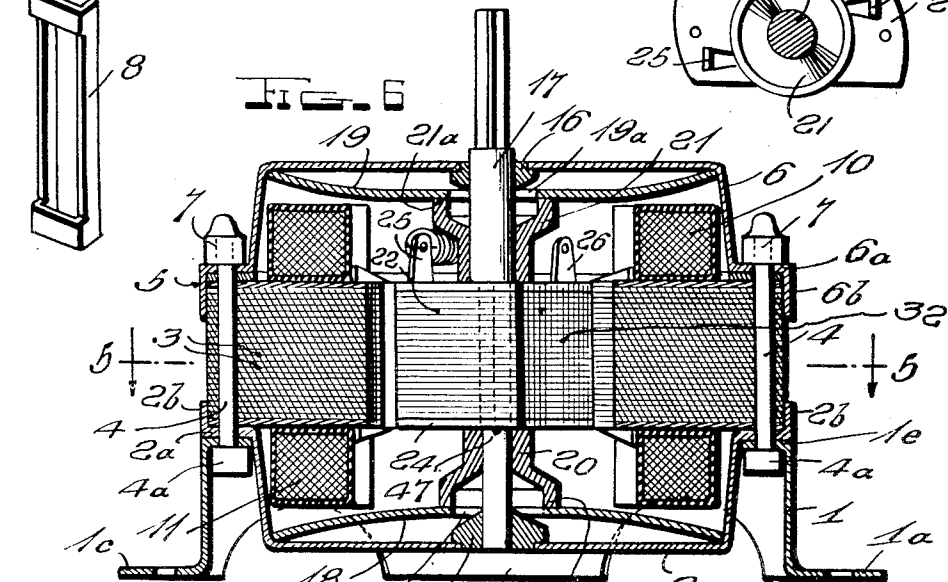


FIG. 6



INVENTOR.
Osborne D. Price
BY

John G. Brady
ATTORNEY

UNITED STATES PATENT OFFICE

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ALTERNATING CURRENT ACTUATOR OR RELAY

Osborne I. Price, Frederick, Md., assignor to Magnetic Devices, Inc., Frederick, Md., a corporation of Maryland

Application June 1, 1948, Serial No. 30,478

6 Claims. (Cl. 175—338)

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My invention relates broadly to electric relays and more particularly to a construction of rotary alternating current actuator for relay.

One of the objects of my invention is to provide a compact construction of electromagnetic rotary actuator or relay having relatively large turning torque and rapid angular movement.

Another object of my invention is to provide a construction of rotary relay having a preformed angularly shiftable magnetic armature coacting with a preformed electromagnetic stator wherein the armature is angularly movable to either of two limiting positions, in one limiting position of which a break is provided in the magnetic circuit at one end of the armature and in the other limiting position of which a shading coil is provided adjacent each end of the armature.

A further object of my invention is to provide a construction of rotary relay including a stator and an angularly movable rotor-armature in which the path of movement of the rotor-armature with respect to the stator is controlled for continuously reducing magnetic reluctance throughout the angular movement of the armature.

Still another object of my invention is to provide a construction of alternating current operated rotary actuator or relay in which the rotor has a substantially three-dimensional rectangular contour with a slight radius in one or two directions at the point of magnetic contact with respect to a coacting stator with breakers of non-magnetic material formed on the faces of the rotor and coacting to reduce the tendency to hum or chatter and preclude sticking when the magnetic faces of the rotor and stator approach each other.

Another object of my invention is to provide a construction of magnetic rotor and stator systems for a rotary relay in which the surfaces of the rotor are convexed or radiused in one or two directions, for reducing the tendency of the structure to hum or chatter under alternating current operation and wherein a coating of non-magnetic material is carried by the rotor at the points of magnetic contact with the stator for preventing freezing.

A further object of my invention is to provide a construction of electromagnetic coil spring biased rotary actuator or relay in which the coil spring bias means are equipped with vibration absorbing means for substantially reducing shock vibration in the coil springs during operation of the device and thereby prolonging the life of the spring many times.

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A still further object of my invention is to provide a construction of mounting means for the rotary armature of an electromagnetic rotary actuator or relay for insuring the precision movement of the rotor within the stator of the device.

Still another object of my invention is to provide a construction of stop ring for a rotor actuator or relay for maintaining the position of a rotary armature with respect to the magnetic poles of a stator during the deenergized periods of the rotary actuator or relay.

Other and further objects of my invention reside in the construction and arrangement of the operating parts of the rotary relay or actuator as set forth more fully in the specification hereinafter following by reference to the accompanying drawings, in which:

Figure 1 is a side elevational view of the rotary actuator or relay embodying my invention; Fig. 2 is a top plan view of the rotary actuator or relay shown in Fig. 1; Fig. 3 is a horizontal sectional view through the rotary actuator or relay taken substantially on line 3—3 of Fig. 6, the view showing the rotor or armature in one of its extreme limits of position under control of the spring bias means and preparatory for angular movement under control of the stator; Fig. 4 is a view similar to the view illustrated in Fig. 3 but showing the armature revolved to the extreme limit of its position when the stator is energized and illustrating the bias control means extended to the extreme limit of extension thereof; Fig. 5 is a horizontal sectional view through the laminated rotor and stator sections of the rotary actuator or relay taken substantially on line 5—5 of Fig. 6; Fig. 6 is a vertical sectional view taken substantially on line 6—6 of Fig. 3; Fig. 7 is a side elevational view of the rotary armature in the rotary actuator or relay of my invention; Fig. 8 is a horizontal sectional view taken substantially on line 8—8 of Fig. 7; Fig. 9 is a perspective view of one of the shading coils employed in the magnetic system in the structure of my invention; Fig. 10 is a plan view of the stop ring employed for restricting the movement of the rotor in its extreme deenergized limiting movement; Fig. 11 is a side elevational view of the stop ring shown in Fig. 10; Fig. 12 is a perspective view of the coil retainer employed for maintaining the electromagnetic actuator windings in position under conditions of the iterative operation; Fig. 13 is a detail view of one of the spring bias which connects the rotor and stator systems equipped with protective

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means for absorbing shock vibration; Fig. 14 is a transverse sectional view taken substantially on line 14—14 of Fig. 13; Fig. 15 is an end view of the rotor on an exaggerated scale showing the manner in which the side faces of the rotor are convexed or radiused slightly in one or two directions; Fig. 16 is a side view of the rotor similarly exaggerated, showing the slightly convexed or radiused sides of the rotor; and, Fig. 17 is a similar elevational view showing the slightly convexed or radiused surface of the rotor.

My invention is directed to a compact construction of rotary actuator or relay which is simple in its design and rugged and reliable in operation and is capable of rapid functioning over a practically indefinite life without failure. I provide a magnetic laminated construction of substantially cylindrical stator having a pair of inwardly directed radially extending stator poles each shaped to coact with a rotary armature. The rotary armature is of three-dimensional rectangular shape which is convexed or radiused slightly in one or more directions for reducing the tendency of the apparatus to hum or chatter under alternating current operation. The armature is mounted for rotary movement with respect to the pole faces of the stator and is spring biased for normally maintaining the rotor in an angular position ready for instant angular movement of the operated shaft on which the rotor is mounted.

The operating shaft may control the movement of electrical contacts, valves, and mechanical and electrical systems, generally. Shading coils may be associated with opposite ends of the rotor or with the poles of the stator. Protective means are associated with the bias springs for absorbing shock vibration under conditions of iterative operation of the device. The electromagnetic actuating windings are maintained in position by means of coil retainers which prevent dislodgement of the windings under conditions of shock to which the apparatus is continuously subjected during operation.

Referring to the drawings in more detail, reference character 1 designates a supporting base of substantially cylindrical construction which is provided with securing feet 1a, 1b, 1c and 1d, for fastening the apparatus to a suitable support. The base 1 is provided with an inwardly directed annular flange 1e forming a seat for the depending cylindrical cup-like member 2 having an annular flange portion 2a which is directly supported on annular flange 1e of base 1. The annular flange 2a has a vertically extending skirt 2b connected therewith serving as a seat for the cylindrical stack of magnetic laminations represented at 3. The stack of magnetic laminations 3 is secured in position by means of bolt members 4 which extend through perforations in the magnetic laminations 3 in a direction normal to the planes of the laminations. Bolt members 4 have headed ends 4a which are confined beneath the annular flange 1e of base 1. The bolt members 4 have threaded ends which project through spaced apertures in the stop ring 5 and through the aligned flange of cup-like member 6 having horizontally extending flange portion 6a in contacting relation with the top of stop ring 5 and having the annular projecting flange 6b extending therefrom and directed toward the flange 2b of cup-like member 2. The threaded ends of bolt members 4 which pass through stop ring 5 and annular flange 6a are secured in clamping position with respect to cup-like member 6 by means of cap screw 7.

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I have found that in building up the cylindrical stack of laminations 3 that each lamination should be coated with varnish by rolling through rubber rollers or the like and the lamination then allowed to dry in air and then assembled. An inexpensive varnish can be used and when the laminations are heated under pressure and then cooled, the complete stack of laminations are for all practical mechanical purpose a tight mass and will withstand considerable abuse without riveting or fastening together by any other mechanical means. I have found that by this procedure the laminations can be milled or ground on the outside circumference, with proper fixtures, making them concentric with the center of laminations and the assembly holes as shown at 31. Also the stator coacting faces can be broached, ground, or machined with ease.

The laminations 3 constituting the stator are formed in a very special shape as illustrated more clearly in Fig. 5. Each inwardly directed pole member 3a and 3b has a composite set of pole faces. The pole faces 3c and 3d are circular and concentric with the center of the device. Pole faces 3e and 3f are connected with pole faces 3g and 3h which extend in spaced parallel relation at approximately 14° to the axis of the device as represented in Fig. 5 by angle A. The pole faces 3e and 3f connect with the sides of the pole members 3a and 3b through pole faces 3g and 3h extending substantially normal to the pole faces 3e and 3f. The pole faces 3e and 3f are grooved at 3i and 3j to permit shading coils 8 and 9 to be retained adjacent the tips of the pole members. The shading coils 8 and 9 are shown more clearly in Fig. 9 and operate to produce a magnetic shift or lag of a portion of the main flux through the magnetic system to such a degree as to reduce the tendency to hum or chatter. The shading coils 8 and 9 are substantially in the shape of elongated rectangles and entirely surround the pole members and establish and maintain a magnetic shift in the field adjacent the tips of the pole members. The shading coils 8 and 9 are preferably formed from copper, although other materials having a higher resistance may be used. The shading coils are formed from flat sheet material which may be readily punch-pressed and shaped so that the coils are readily maintained on the pole members even under conditions of iterative shock. Both coils 8 and 9 are symmetrical so that there is no right or left to be considered in the assembly process.

The laminations 3 are each provided with chordal portions 3k and 3l which extend in spaced parallel relation to each other on opposite sides of pole members 3a and 3b. Electromagnetic operating windings 10 and 11 each well taped with insulation material are positioned over the pole members 3a and 3b, as shown in Figs. 3, 4 and 5, and are secured in position against shock vibrations by means of coil retainers 12 and 14. The structure of the coil retainer is shown more clearly in Fig. 12 wherein coil retainer 12 has been illustrated in perspective view. The coil retainer 12 is provided with a pair of angularly disposed arms 12a and 12b interconnected by an intermediate flat portion 12c which bears against the chordal portion 3l of the laminations 3. The arms 12a and 12b each have a lug 12a' and 12b' extending therefrom and engaged over the pole members 3a and 3b as I have represented at 3n and 3m in Fig. 3. The coils retainer 14 is constructed in a similar manner and has lug members engageable over

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opposite sides of pole members 3a and 3b in a manner similar to the lug engagement described for coil retainer 12.

The cup-shaped members 2 and 6 form end bells, each of which carry bearing members 15 and 16, respectively, serving as journals for the angularly shiftable shaft 17. The angularly shiftable shaft 17 is spaced with respect to the end bells 2 and 6 by means of resilient shock plates 18 and 19 which are bowed inwardly and centrally apertured at 18a and 19a for the passage of shaft member 17. Spacer members 20 and 21 are disposed between the opposite ends of the magnetic armature assembly represented at 22 and the shock plates 18 and 19. The spacer members 20 and 21 are tubular in section and fit around the shaft 17 and are flared outwardly to present an annular peripheral bearing face at 20a and 21a forming an abutment with the inner face of shock plates 18 and 19, respectively. Thus the angularly movable armature is positioned for precision angular movement between the pole members 3a and 3b.

The armature assembly 22 constituting the rotor is formed from a stack of magnetic laminations secured on the square section of shaft 17 as shown in Fig. 5. The laminations may be riveted with respect to the end laminations and maintained in a stack by a suitable varnish or other adherent which is baked for a suitable time period at high temperature for forming the coherent armature assembly. The rotor shaft 17 of square cross section throughout the portion that extends through the laminations and is circular throughout the journalling portions. The ends of the stack of laminations are protected by end plates 23 and 24 which may be provided with suitable indents projecting inwardly into the stack of laminations. End plate 23 is provided with outstruck upstanding lugs 25 and 26 which serve as connecting means for the ends of the coil springs 27 and 28. The opposite ends of coil springs 27 and 28 are secured to upstanding lugs 5a and 5b on stop ring 5, as shown in Figs. 3 and 4. The stop ring 5 has inwardly extending diametrically disposed portions 5c and 5d, each of which have a downwardly projecting face 5e and 5f coextensive therewith. Those faces 5e and 5f serve as limiting stops for the movement of the rotor. It will be observed that the faces 5e and 5f are disposed at an angle of 31° to the horizontal, whereas, the adjacent connecting edges coextensive with the inwardly directed stop faces are disposed at 45° with respect to the vertical, as represented in Fig. 10. The apices of the inwardly directed stop faces terminate above and below a center line drawn through the stop ring as represented in Fig. 10. By this construction I have found that it is possible to very accurately control the movement of the rotor. The rotor is a very special construction. The magnetic laminations thereof are substantially coplanar with the laminations of the stator 3. The opposite faces and ends of the rotor may be milled or ground. In Figs. 15-17, I have illustrated, on an exaggerated scale, the manner of milling or grinding the opposite faces of the stack of magnetic laminations 22, so that there is a high point in the center of one face of the armature at 29 and on the opposite face of the armature at 30. From the high points 29 and 30, the opposite faces of the magnetic armature 22 are convexed or radiused slightly in one or two directions. This structure considerably reduces tendency of the armature and the appara-

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tus to hum or chatter under control of alternating current operation. Moreover, the magnetic circuit through the rotor and stator is broken by a coating of non magnetic or non ferrous material such as copper, zinc, cadmium, chromium, etc., which is coated over the faces 29 and 30 at those portions thereof which may contact with coating pole faces of the stator pole members, thus constituting a breaker or minute air-gap and preventing freezing of the parts.

The armature 22 is further designed in a very special manner to provide receding end faces on the armature as represented at 31 and 32. I have found that maximum efficiency may be obtained by grinding the ends of the armature so that the circumference of the lamination recedes at a rate of .001" per degree. The amount of recession can be changed and increased or decreased per degree, which will in turn change the characteristics of the operation of the device. The pole faces 3c and 3d of the pole members of the rotor may be made to recede and the ends of the rotor rounded, or both the rotor and the stator may have receding pole faces. With a recession of a .0005" per degree I had secured a starting torque of 80 inch ounces and this dropped off to 40 inch ounce in turning 45 degrees. I made another rotor for the same device with a recession of a .00075" per degree and this rotor had a starting torque of 60 inch ounces and had a torque of 50 inch ounces through the rotation of 45 degrees. I then made another rotor with a recession of .001" per degree and found the starting torque to be 56 inch ounces and a torque of 52 inch ounces through the 45 degrees movement.

I found that by varying this recession up and down that a characteristic curve could be developed to fit into many applications. For instance, it is possible by changing this curve to obtain a high starting torque which will diminish greatly until it reaches approximately 22-30 degrees movement and then will increase again until the end of the stroke. By changing this curve in other ways many different operating characteristic curves can be obtained.

The entire operation of this device rests on the reduction of reluctance through the movement of the armature and so long as the reluctance of the magnetic path continues to decrease, the armature or rotor will continue to rotate until it reaches the stop which is a part of the laminations or field structure, as shown at 5e and 5f. It was found that in the position as shown in Fig. 4, which is the end of rotation a substantially complete and closed magnetic circuit is formed by the rotor and the stator sections except for the breaker coating. Due to the high degree of magnetization it was found that the rotor would stick very tightly to the pole faces or stops as shown in either of the limiting positions in 4 and 3, and would not release even when 35 inch ounces of spring return torque was applied to the rotor. When, however, the rotor faces coming in contact with the stator pole faces 3e and 3f were plated about .0015" thick or less at these points, the release was found to be immediate, due to the fact that a "breaker" was formed in the magnetic circuit which was equivalent to a small air-gap in the magnetic circuit as the copper face was non ferrous or non magnetic. Other materials in the place of copper such as zinc, cadmium, chromium, etc., may be used, as heretofore explained; or any other form of "breaker" to form a gap in the magnetic circuit may be provided.

I have found that instead of copper-plating the rotor, I may finely sand blast or etch the rotor and then plate the entire rotor, shaft and all, with chromium and this chromium needs to be but .001" to .0002" in thickness. The chromium-plating of the rotor all over has many advantages. It inhibits rust to a certain extent, and is very much less costly as the entire rotor is plated instead of just a small section. The chromium-plate is very hard and the life of the device is lengthened considerably due to the hard surface coming in contact with the softer surfaces of the stator. The plating only has to be very thin. This provides a hard coating on the shaft where the shaft turns in the bearings. When the rotor goes closed magnetically and the magnetic circuit is made substantially magnetically tight, a breaker is provided by the plating on the rotor on contacting faces which insures a breaker at two points of a circuit that would otherwise be magnetically tight, except, for the plating.

In order to keep the device from humming or chattering the shading coils 8 and 9 were placed in the grooves 3i and 3j in the stator as shown in Figs. 3, 4 and 5. This shading coil is preferably made of copper, although other materials having a fairly low resistance could be used. The shading coil as shown in Fig. 9 is made of sheet copper so as to be easily manufactured on a punch-press. This shading coil shifts a portion of the main flux to such a degree as to reduce the tendency to hum or chatter. The coils are wound on a machine and are bent to shape after being wound for easy manufacture.

It will be noted the rotor is in the energized position in Fig. 4. This figure shows the rotor with a 45 degree rotation. The rotation in the deenergized position is controlled by the stop ring 5 as shown in Fig. 3.

It will be noted that two ears or lugs 5a and 5b are lanced from ring 5 as shown in Figs. 3, 4, 10 and 11. The ears as shown at 5a and 5b have a small hole punched therein which are used as anchors for one end of each of the return springs 27 and 28. The two ears, lugs, or stops 5e and 5f are bent the opposite way as shown in Figs. 10 and 11 so as to form the stops for the rotor in the deenergized position. It will be observed that end plate 23 is made of brass, although it could be made of other non-magnetic materials. Plate 23 has the ears or lugs 25 and 26 lanced from same to form anchors for the other end of the return springs 27 and 28.

The armature or rotor is substantially in the shaped of a parallelopiped with rectangular side faces substantially laminated, as it is to be used on alternating current and as the laminations are thin, I added a heavier piece of magnetic material as shown at 24.

The rotor shaft 17, the laminations 22, end plate 23 and the rotor end plate 24 are assembled to form the complete rotor unit. It will be observed that the shaft 17 is square with one corner machined off so that it is impossible to assemble these parts, except in the right way. Each of these parts 23, 17, and 24, have "indents" which register one with another which maintain alignment and keep the parts from shifting due to high impact of the rotor at each end of its movement against the stops.

When the device is assembled the rotor has the spacers 20 and 21 at each end as shown in Figs. 6 and 7, and it will be noted that these spacers have large openings at the large end of

each and of sufficient depth so as to clear the bearings 15 and 16 should the rotor have movement to one end or the other.

These spacers rest on shock plates 18 and 19 as shown in Fig. 6, and these shock plates are purposely made saucer-shape and fit into each end bell 2 and 6. The shock plates have been found very essential as this particular device was subjected to 2,000 ft. lb. shock and without them the end thrust was taken on the bearings directly and bulged the end bells to such an extent as to make the device inoperative. These shock plates fit fairly snug in the end bells 2 and 6 as shown in Fig. 6. When these shock plates start to collapse or flatten out they get tighter and tighter within the bells 2 and 6, which in turn continually increases the pressure necessary for the flattening of these shock plates and therefore absorbs the given shock in less distance.

The end bells 2 and 6 as shown in Fig. 6 are both alike for ease of manufacture, except for the two bulges 46 and 47, shown in Fig. 2, which serve to support the terminal assemblies 43 and 44.

After the entire assembly is made it will be noted that the shaft 17, which has end extensions, is of the same shape or section as the portion on which the laminations of the rotor 22 are assembled. However, these extensions can be round or any other shape that may fit into the structure to be added, such as switches, etc. I do not wish to limit myself to making this device strictly a relay as it can be used for many other uses and mechanical movements, or a shaft can be extended from the bearings at each end of the device and gears to multiply, divide, the movements can be utilized, or in many various ways to utilize rotary motion through a predetermined angle or oscillating movement.

I have found that the rotor when completely assembled may be ground with a slight radius in both directions on one or both sides of same of only a thousandths of an inch or more as shown in Figs. 15, 16 and 17, that the operation of the relay from the stand point of hum or chattering is greatly improved as it is practically impossible to have these faces absolutely in parallel contact with the stator laminations, and by this slight radius the rotor can accommodate itself with a rocking chair motion when the surfaces are in contact. This radiusing is not absolutely necessary as very flat faces can be used although more costly.

In order to reduce vibration of the pair of coil springs 27 and 28 under iterative operation, I have introduced a core of round felt 33 conforming to the internal diameter of the coil spring as represented in Figs. 13 and 14. The felt snugly engages the interior of the convolutions of the springs and serves to absorb vibration of the springs under conditions of shock vibration to which the structure is subjected during operation. In tests, with these felt inserts 33 installed, I have operated the device of my invention over a period of time to perform 200,000 operations without a failure.

The shaft 17 may control a variety of mechanical or electrical devices or valves. For purposes of illustrating one application of my invention, I have shown, in Fig. 1, a cylindrical switch housing 34 mounted on the top of the end bell 6 and enclosing a multiplicity of electrical contactors having terminal contactor means represented at 35, 36, 37, 38, 39 and 40, to which electrical connections may be made. The shaft 17 may carry a

wafer-type switch angularly shiftable within the housing for making periodic connection with the contactors connected to terminals 35—40. The switch housing may be readily opened or closed by removal of top plate 41 secured in position by cap screws 42. Circuit connections are made to the electromagnetic operating windings 10 and 11 encased by the end bells 2 and 6 through terminals 43 and 44 supported on panels of insulation material 45 and 46 mounted on one side of end bell 6.

The switch structure is very substantially encased to protect the moving parts against moisture, corrosion, and the elements, and so far as observations to date indicate, necessity for maintenance and repair are almost negligible. Very effective and reliable service has been obtained by use of the device of my invention under very exacting conditions.

While I have described certain preferred embodiments of my invention I realize that modifications may be made and I desire that it be understood that no limitations upon my invention are intended other than may be imposed by the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. A rotary actuator comprising a stator including a pair of inwardly directed pole members each having composite curved and angularly disposed pole faces, an angularly shiftable armature journaled for angular displacement with respect to said pole faces, said armature being formed substantially in the shape of a parallelopiped having opposite side faces, a plate member carried by said stator, a pair of stops integrally connected with said plate member and directed inwardly into the path of movement of said armature for limiting the angular movement of said armature in one direction, said angularly disposed pole faces limiting the movement of said armature in the opposite direction, means connected between said plate member and said armature for biasing said armature to a position in which the side faces of the parallelopiped armature normally abut with said stops, electromagnetic means associated with said pole members for exciting said pole members and effecting angular movement of said armature to a position in which the side faces of the parallelopiped armature abut said angularly disposed pole faces and an operating shaft extending from said parallelopiped armature.

2. A rotary actuator comprising an annular supporting base terminating in a flat circular inwardly directed flange, a bell-shaped end member supported by said flange and projecting concentrically inwardly of said base, a cylindrical stator supported by said bell-shaped end member, an oppositely positioned bell-shaped end member supported on said cylindrical stator and projecting outwardly therefrom, bearings supported centrally of each of said bell-shaped end members, a shock plate disposed in each of said bell-shaped end members and apertured in alignment with said bearings and extending in transverse spaced relation thereto, a rotor shaft journaled in said bearings and extending through the aperture in said shock plates, an armature mounted on said shaft and aligned with said stator, and tubular spacer members formed by metallic sleeves surrounding said shaft and disposed between the opposite ends of said armature and said shock plates.

3. A rotary actuator comprising an annular supporting base terminating in a flat circular inwardly directed flange, a bell-shaped end mem-

ber supported by said flange and projecting inwardly of said base, a cylindrical stator supported by said bell-shaped end member, an oppositely positioned bell-shaped end member supported on said cylindrical stator and projecting outwardly therefrom, bearings supported centrally of each of said bell-shaped end members, a resilient centrally apertured shock plate disposed in each of said bell-shaped end members, a rotor shaft journaled in said bearings and extending through said centrally apertured shock plates, an armature mounted on said shaft and aligned with said stator, and tubular spacer members disposed around said shaft at each end of said armature and having enlarged sections on each end thereof establishing angular sliding connection with said shock plates.

4. A rotary actuator comprising a cylindrical stator including a pair of inwardly directed pole members each having composite curved and angularly disposed pole faces, an angularly shiftable armature journaled for angular displacement with respect to said pole faces, a circular plate member carried by said cylindrical stator and having inwardly directed projections thereon, a pair of stops carried by the projections on said plate member for limiting the angular movement of said armature in one direction, means fastening said circular plate member to said cylindrical stator, said angularly disposed pole faces limiting the movement of said armature in the opposite direction, means connected with said plate member for biasing said armature to a position normally abutting said stops, electromagnetic means associated with said pole members for exciting said pole members and effecting angular movement of said armature to a position abutting said angularly disposed pole faces and an operating shaft extending from said armature, the end faces of said armature which coast with the curved faces of said pole members each receding in opposite directions at the rate of approximately .001" per degree of angular path of movement of the armature.

5. A rotary actuator comprising an operating shaft, an armature carried by said shaft, a stator surrounding said armature and having inwardly directed pole members thereon extending on opposite sides of the path of movement of said armature, pole faces on said pole members for limiting the angular movement of said armature in one direction, a stop ring supported by said stator and having inwardly directed portions thereon projecting into the path of movement of said armature intermediate said pole members, stops integrally connected with said projections and extending in planes normal to the plane of the projections for limiting the angular movement of said armature in opposite directions, connection means adjacent said armature, aligned connection means on the projections on said stop ring and coacting projections on said armature aligned with the aforesaid projections, and coil springs extending between said connection means for yieldably urging said armature into abutment with the stops on said stop ring during unexcited conditions of said pole members.

6. A rotary actuator comprising an operating shaft, an armature carried by said shaft, a stator surrounding said armature and having inwardly directed pole members thereon extending on opposite sides of the path of movement of said armature, pole faces on said pole members for limiting the angular movement of said armature in one direction, a stop ring supported by said

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stator and having inwardly directed portions thereon projecting into the path of movement of said armature intermediate said pole members, sets of integrally formed projections adjacent each of the inwardly directed portions of said stop ring, the projections of each set extending in opposite directions in spaced positions, one projection adjacent each of said inwardly directed portions extending in a plane normal to the plane of the stop ring and constituting a stop for limiting the angular movement of said armature, and the other projection adjacent each of said inwardly directed portions forming a connecting means, a pair of coil springs, and connecting means on each side of said armature in alignment with the connecting means adjacent the inwardly directed portions, said coil springs being interposed between aligned connecting means whereby said armature is yieldably maintained in a position abutting said stops in the unexcited condition of said pole members.

OSBORNE I. PRICE.

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