

May 28, 1957

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MAGNETICALLY ACTUATED AND HELD BALL ARMATURE
SWITCHING DEVICES

2,794,178

Filed April 5, 1954

2 Sheets-Sheet 1

Fig. 6.

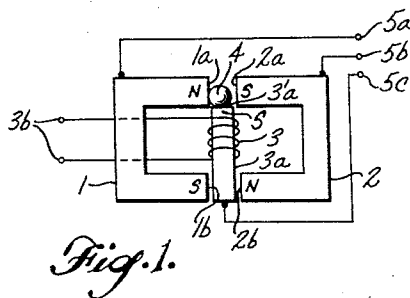
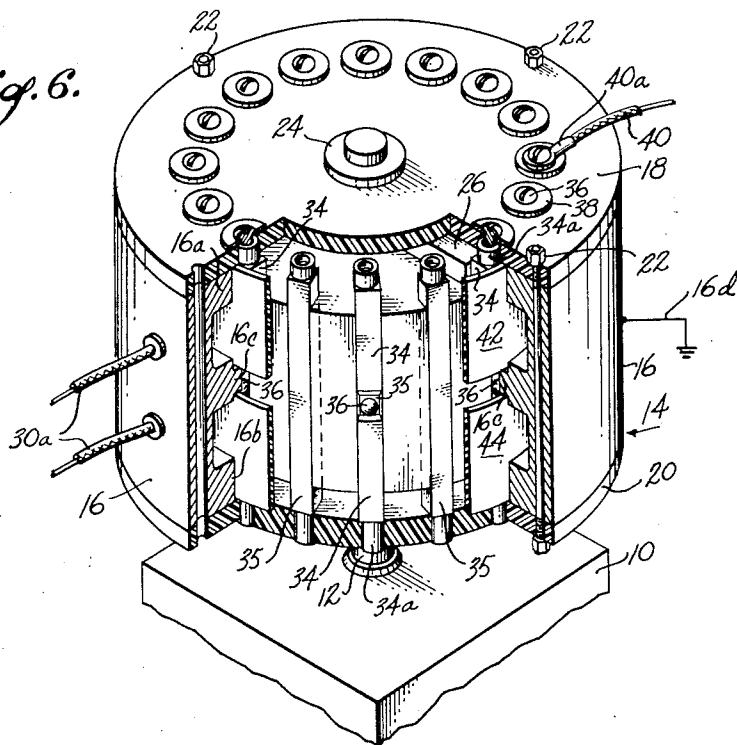


Fig. 1.

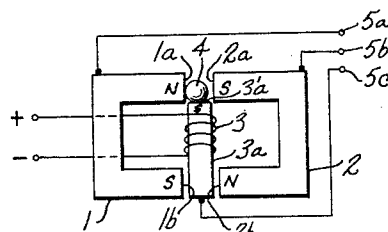


Fig. 2.

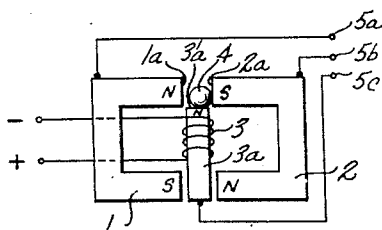


Fig. 3.

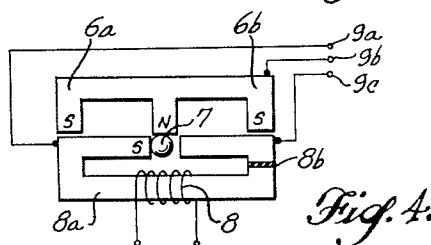


Fig. 4.

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Fig. 5.

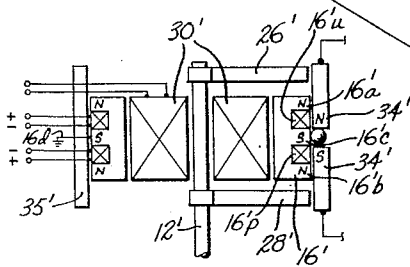
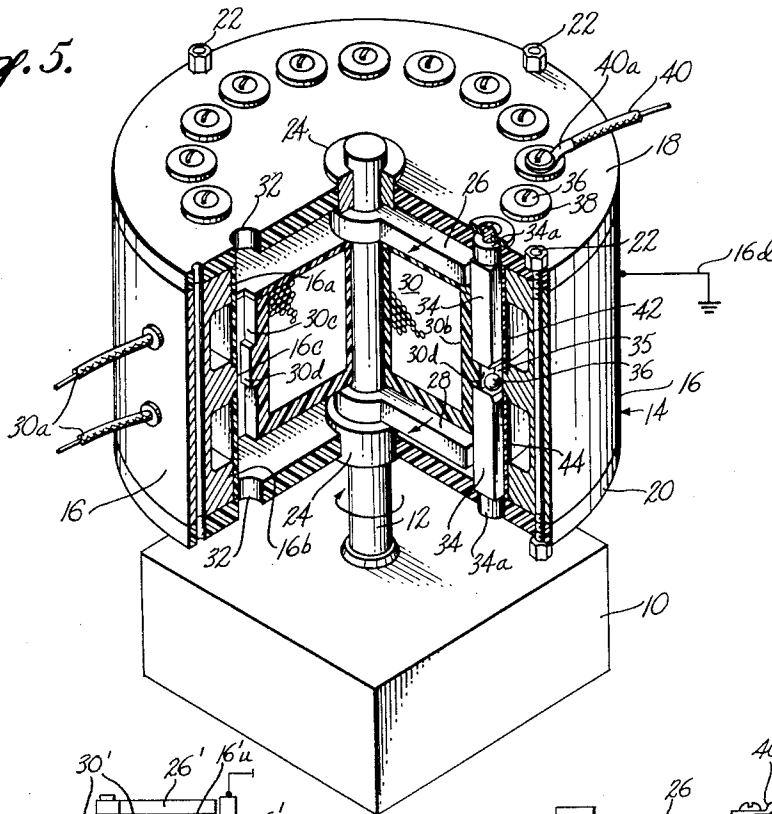


Fig. 9.

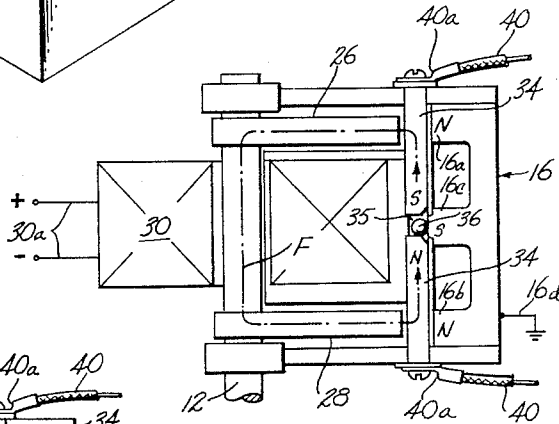


Fig. 7.

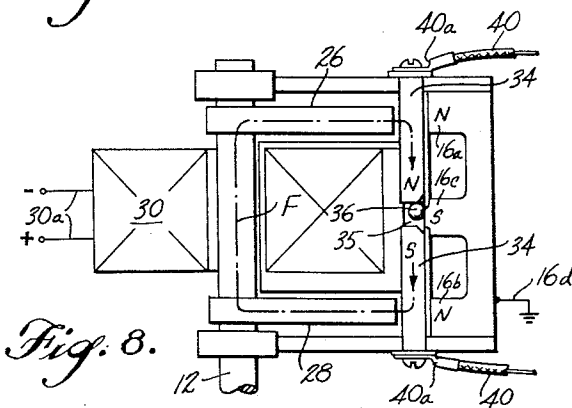


Fig. 8.

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2,794,178

MAGNETICALLY ACTUATED AND HELD BALL ARMATURE SWITCHING DEVICES

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Application April 5, 1954, Serial No. 421,058

10 Claims. (Cl. 340—147)

This invention relates to a magnetically actuated and held selective switching device and further to a sequentially operated multiple switch unit selective switching device basically similar to the rotary multipole type disclosed in the copending application of Leroy C. Perkins and Francis D. Reynolds, Serial No. 288,254, filed May 16, 1952. The novel magnetic switch actuating and holding arrangement when embodied in a sequentially operated multiple switch unit form as herein disclosed greatly reduces or eliminates mechanical wear relative to that experienced with a device in which the switch elements are held in resiliently deflected actuated position by sliding against a rotary barrier member as in the above-cited application. The present invention is herein illustratively described by reference to its presently preferred form, but it will be readily appreciated that certain changes and modifications therein may be made without departing from the essential features presented.

An object of this invention is to provide a low-cost highly sensitive relay or selective switching device in which a magnetically actuated armature or movable element is held with great retentivity in any of a plurality of actuated positions so as to withstand unusually high acceleration forces tending to dislodge it. A related object is such a relay device wherein little or no wear of electrical contacts can occur and no failure of moving or flexible parts through extensive use as in the case of ordinary relays. Still another object is such a relay device in which a slight amount of wiping or rubbing action inherently takes place between the electrical contact surfaces during relay actuation, thereby to establish a low-resistance electrical contact therebetween but to a degree insufficient to create a wear problem.

An individual relay or selective switching unit incorporating features of the invention in one form comprises a free or "floating" ferromagnetic ball as the magnetically actuated and held switching element and a combination of permanent magnetic and soft core electromagnet elements. The term "permanent magnetic" or like terms as herein used is intended to include continuously energized electromagnets as well as true permanent magnets comprising magnetized elements having a high degree of magnetic retentivity. In some applications of the invention it may be preferable to employ true permanent magnets such as Alnico magnets in the magnetic field structure of the relay device, whereas in other instances it may be desirable to utilize an arrangement of electromagnets. In all cases the ferromagnetic ball is retained in an interpole space wherein it remains in contact with one magnetic pole face and is magnetically shifted into contact with either of two additional pole faces adjoining the first by temporary magnetization of the ferromagnetic core system of the device, such ball being held by permanent magnetic flux in either of said shifted positions.

With a permanent magnet of even moderate strength according to present-day standards the ball armature of the switching device is held in any actuated position with great retentivity, one reason for this being that the ball

need not be large or massive and the permanent magnetic flux creating the retaining force is concentrated largely in or through the ball. Moreover, the process of magnetically actuating the ball between positions inherently produces slight rotation thereof hence a wiping action of its surface on the pole faces into which it comes in contact, thereby affording good electrical contact therebetween.

In both the copending patent application cited above and in the sequentially operated, multiple switch unit form of the present invention the switch contact elements are actuated electromagnetically, that is, by application of selective control impulses to the field winding of rotary flux concentrating means. The pulses are applied in timed relation to mechanical scanning movement of the flux concentrating means past switch contact elements arranged in circular series relationship for sequential selective actuating purposes. In said copending application the magnetic flux concentrator was mounted for rotation with an annular barrier member having a notch or opening in one edge thereof adjacent the flux concentrator, permitting the latter, if then magnetized, to attract through such opening any switch contact element then in registry with it. In the absence of such magnetization at the time of passing, the switch contact element would remain in its unactuated position on the original side of the rotary barrier member or, if previously actuated, would return to unactuated position through said opening by resilient recoil. By applying a pulse of energizing current to the magnetic field winding at the instant of such registry the switch contact element would be drawn against its own resilient force through the opening and held on the opposite side thereof magnetically for a period of time sufficient to be trapped there by the barrier member's continuing rotation. The actuated switch contact element would thus remain trapped in sliding contact with the barrier member throughout the latter's full rotation cycle, at the completion of which it would return through the opening to the original side of the barrier member if the magnetic field winding were not again energized at that instant. Any practical number of switch contact elements could thus be actuated in sequential selective manner for decoding and memory of sequential digital pulse commands in remote control applications, for digital computer operations and generally for electrical switching operations in any of various types of apparatus. Such a device can be made very compact and will be capable of replacing much more complex, bulky and expensive electronic switching apparatus necessary for accomplishing essentially the same results. Moreover, by ordinary standards applied to mechanical switching devices, the former device could be made in relatively durable form.

In accordance with the present invention there are substituted for the resilient ferromagnetic switch contact reeds an equal number of switch contact ferromagnetic balls. A permanent holding magnet of annular form arranged to cooperate with selectively magnetizable flux concentrators or soft core pole pieces causes the balls to be attracted and held individually in either of two positions in which they bridge between magnetic pole faces as switch contact surfaces. With this novel arrangement it is unnecessary to rely upon resilient deflection for switch contact movement, also the problem of mechanical wear is eliminated, since in either of the two alternative positions of the switch contact balls they rest against stationary surfaces and there is no sliding contact sufficient to produce wear.

As a further feature of the sequentially operated multiple switch unit form, flux diverters or shorting bars are mounted in the spaces between successive sets of pole pieces to prevent magnetic flux set up in one switch unit from straying into the adjoining unit and affecting the position of the ball armatures cooperating in the latter.

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These and other features, objects and advantages of the invention will become more fully evident from the following description by reference to the accompanying drawings.

Figure 1 is a simplified and partially schematic side view of a selective switching device or relay incorporating features of the invention, and Figures 2 and 3 are similar views of the same device under different operating conditions.

Figure 4 is a corresponding view of a modified form of the relay.

Figure 5 is a perspective view of the sequentially operated multiple switch unit form of the invention with a portion thereof broken away to reveal details of interior construction. Figure 6 is a similar view wherein a different portion of the structure is broken away to reveal still other details. Figure 7 is a schematic or simplified sectional side view taken along the axis of the device for illustrating a switch contact ball in one switching position. Figure 8 is a view similar to Figure 2 in which the same switch contact ball is shown in its alternate switching positions.

Figure 9 is a simplified and partially schematic axial sectional view of a modified arrangement of the device shown in Figure 5 et seq.

Referring to Figure 1, the U-shaped permanent magnets 1 and 2 have opposing upper and lower pole faces 1a, 2a and 1b, 2b respectively of unlike polarity. Thus the upper pole face 1a is a north magnetic pole and the opposing pole face 2a, arranged generally parallel thereto, is a south magnetic pole. A soft core 3a in the form of a non-retentive ferromagnetic bar comprising the core of electromagnet winding 3 cooperates with the two permanent magnets. The bar 3a lies between the lower pole faces 1b and 2b and extends therefrom to a point adjacent a space between the upper pole faces 1a and 2a such that its end face 3'a lies generally perpendicular to and mutually adjoining the pole faces 1a and 2a. An armature ball 4 of ferromagnetic material rests in contact with the electromagnet core pole face 3'a and one of the permanent magnet pole faces 1a or 2a.

In the absence of energization of the electromagnet winding 3 by application of voltage to the input terminals 3b, the core 3a assumes a polarity opposite that of the permanent magnet pole face contacted by the ball 4. In effect the ferromagnetic core 3a constitutes a pole piece for said permanent magnet and the ball 4 is firmly retained by magnetic attraction in contact with the pole face 3'a and the particular permanent magnet pole face. In Figure 1 the conductive ball bridges between the conductive pole faces 1a and 3'a, thereby closing an electric circuit between relay output terminals 5a and 5c connected to magnet 1 and core 3a, respectively. Energization of electromagnet winding 3 with the polarity indicated in Figure 2 has no effect on the switching position of ball armature 4 since it merely adds to the permanent magnetic flux sustained in core 3a from permanent magnet 1. However, energization of electromagnet winding 3 with opposite polarity, if of sufficient magnitude, produces magnetic flux in the reverse direction in the core 3a and thereby causes the pole face 3'a to assume a magnetic polarity like that of the permanent magnet pole face 1a then contacted by the ball (Figure 3). The ball is thus repelled by the latter pole face and is attracted to the opposite permanent magnet pole face 2a. In transit the ball remains firmly in contact with the intermediate pole face. The ball is now magnetically retained in its new switching position closing a circuit between output terminals 5b and 5c after the source of energy is removed from winding 3. Preferably the ball 4 and the pole faces are plated with a highly conductive metal for establishing low-resistance contacts.

In the modification appearing in Figure 4 a different configuration is used for the permanent magnets and also for the core of the electromagnet. In this case the perma-

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nent magnets 6a and 6b comprise the end portions of an E magnet structure and have a common pole (north, in the example) located generally intermediate the ends thereof. The face of this intermediately situated common pole is continuously contacted by the ball armature 7. The electromagnet winding 8 in this instance is wound on the C shaped low-retentivity ferromagnetic core 8a. The end faces of this electromagnet core are disposed adjacent opposite sides of the above-mentioned permanent magnet pole face to be engaged alternately by the ball 7. The two end or south pole faces of the permanent E magnet lie close to the core at locations back of the respective pole faces of the latter such that the opposite end portions of the core 8a serve as pole pieces for the two permanent magnets when the coil is unenergized. The core 8a is segmented and electrical insulating material 8b is interposed between the segments as shown. Relay output terminals 9a, 9b and 9c are connected respectively to one end segment of core 8a, to the E magnet and to the opposite end segment of core 8a.

In the operation of the modified relay appearing in Figure 4, the position assumed by the ball is dependent on the polarity of previous energization of electromagnet winding 8. The ball then contacts that pole face of the core 8a which was given a polarity opposite that of the intermediately situated E magnet pole. In the example the latter pole is a north magnetic pole and the ball contacts this pole and the left-hand or south pole of the core 8a. Energization of the winding 8 to reverse the polarity of the core 8a will cause the ball to be repelled and attracted to the right-hand pole of the core 8a. The ball remains in either of its two alternate actuated positions when energization is removed from the coil 8, since under that condition the magnetic attraction of the ball to the core pole face being contacted by the ball at any instant is greater than that to the opposite core pole face due to the greater concentration of magnetic flux sustained in the former by virtue of the low-reluctance path furnished by the ball 7.

In certain instances wherein electromagnet energizing conductors would be a handicap the electromagnet means of the relay device can be replaced by a ferromagnetic structure which is temporarily magnetized by positioning of an external magnet in the vicinity of the device in order to pass ball actuating magnetic flux through the interpole space in a sense causing the ball to shift to an alternate position.

Referring now to the multiple relay form involving sequential selective operation as illustrated in Figures 5 et seq., there is shown a drive unit 10 which may be of any type suitable for rotating the switch device shaft 12 in the desired manner. Such rotation may be intermittent, continuous, or may occur by increments relative to the fixed switch device casing 14, depending upon the requirements of a particular application. The switch device casing is generally cylindrical and is formed by the annular permanent magnet 16 having three inwardly projecting flanges extending around the inside periphery thereof. These flanges are located respectively at top, bottom and intermediate positions heightwise of the cylindrical form. The intermediate flange 16c constitutes a magnetic south pole in the example, whereas the top and bottom flanges constitute magnetic north poles, so as to set up two co-existing magnetic fields of generally annular form inside the casing. Circular plates 18 and 20 of insulating material furnish top and bottom covers for the casing and are clamped in position on the opposite end faces of the cylindrical permanent magnet 16 by means of four clamp bolts 22 spaced equidistantly around the circumference of the casing and passing through the web of the magnet. Journals 24 are received in central openings in the respective cover plates 18 and 20 for rotationally supporting the shaft 12 extending along the axis of the casing.

Two ferromagnetic flux concentrator arms 26 and 28

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are rigidly mounted on the shaft 12 to project at right angles therefrom in the same angular direction at respective locations immediately adjacent the inside faces of the top and bottom cover plates 18 and 20. The shaft 12, or at least that portion of the shaft between the flux concentrator arms 26 is also of ferromagnetic material. In the space, lengthwise of shaft 12, between the flux concentrator arms is mounted a solenoid 30 surrounding the shaft 12, but structurally supported from the casing in a manner to be described so that the shaft 12 and with it the arms 26 and 28 can be rotated freely while the solenoid remains stationary. Two openings are provided through the side of the permanent magnet through which the opposite ends of the insulated conductor 30a forming the solenoid may project for connection to a suitable source of energizing current.

The top and bottom insulating cover plates 18 and 20 have an equal number of holes arranged in circular series relationship and at corresponding locations about the axis of shaft 12. These holes serve as supporting sockets receiving the cylindrical base portions 34a of the barlike ferromagnetic pole pieces 34 and of the magnetic flux diverting or shielding bars 35 located in alternate series arrangement with the pole pieces in the annular space lying generally between the annular casing magnet 16 and the peripheral wall of the solenoid shell 30b. The barlike magnetic pole pieces 34 are arranged in pairs, the two members of each pair being aligned parallel to the axis of shaft 12 and being each of a projecting length less than half the distance between the inside faces of the cover plates 18 and 20 so as to leave open spaces or cavities between the projecting ends of the members of each such pair of pole pieces. These interpole spaces are adjoined by the inside face of the annular permanent magnet pole member 16c. Small ferromagnetic balls or armature elements 36 are received in the respective interpole spaces 35 and are free to move up and down in those spaces into and out of direct physical contact with the ends of the two pole pieces 34 while being in direct physical contact with the face of the annular pole 16c. Preferably these balls and also the three pole faces which they may contact are silver plated for establishing good electrical contact surfaces.

The upper pole pieces of each pair (34) and the upper ends of the flux shielding bars 35 are secured to the top cover plate 18 by screws 36 and washers 38 and the lower pole pieces and the lower ends of the bars 35 are similarly secured to the bottom cover plate 20. The screws 36 serve as fastening elements for the connection of terminal lugs 40a of electrical conductors 40 to the respective pole pieces and bars. The pairs of pole pieces 34 thus rigidly mounted inside the switch device casing serve as the primary supporting means for the solenoid 30. The solenoid coil is received inside a solenoid shell 30b of insulating material having a cylindrical outer portion which is notched radially at the locations of the pairs of pole pieces to accommodate such pole pieces in the respective notches. Also, these notches, designated 30c, have radially inner surfaces which are not flat but have intermediate projections 30d forming top and bottom shoulders against which the tip faces of the two pole pieces abut when received in the notches 30c. However, the radial width of the pole pieces is greater than the extent of the projections 30d relative to the inner walls of the notches 30c so that the projections 30d do not completely occupy the interpole spaces but leave room for the free up and down movement of the ferromagnetic switch contact balls 36 necessary for such balls to move between positions of contact with the top and bottom pole pieces 34 associated respectively with them. The notches 30c receiving the fixed pole pieces, and the projections 30d abutted by the pole piece tips provide fixed support for the solenoid shell centrally in the housing 14 and thereby maintain the necessary open spaces inside the ends of the

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housing for free rotation of the flux concentrator arms 26, 28 inside the housing.

Two thin rings 42 and 44 of insulating material separate the radially outer faces of the pole pieces from the permanent magnet 14 and thereby electrically insulate the respective pole pieces from such magnet. Since the cover plates 18 and 20 and the solenoid shell 30b are themselves of insulating material the pole pieces 34 are individually insulated from each other. The pole pieces serve as separately insulated electrical switch contacts, and the permanent magnet 16 as a ground contact.

The radial length of the ferromagnetic flux concentrator arms 26 and 28 is slightly less than the radial distance to the inside faces of the pole pieces 34, so that the latter do not interfere with free rotation of such arms when the shaft is turned. However, the distance separating the ends of the arms from the pole pieces is sufficiently small that magnetic flux set up by energization of the solenoid 30 readily traverses the gap and passes into and through the pole pieces. The magnetic flux path attending energization of solenoid 30 with one polarity is represented by the broken line F in Figure 7. In Figure 8 the polarity of solenoid energization has been reversed with the result that the magnetic flux extends in the opposite direction, although in the same path as shown in the preceding figure. In the first case (Figure 7) the lower pole piece of a particular pair becomes the north magnetic pole, whereas in the latter instance (Figure 8) the upper pole piece becomes the north magnetic pole. The ferromagnetic switch contact ball 36 in the particular interpole space remains at all times in electrical contact with the face of the intermediate flange 16c of the permanent magnet 16. In effect, therefore, this switch contact ball constitutes a movable south pole extension of the permanent magnet 16, and when the solenoid is energized with the polarity shown in Figure 7 the ball is drawn downwardly into electrical contact with the associated lower pole piece, whereas if the solenoid is energized as in Figure 8 the ball is drawn upwardly into contact with the upper pole pieces of the particular pair. In either case the ball bridges electrically between the intermediate flange of the permanent magnet casing 16 and one of the pole pieces of the pairs of pole pieces. The flux shielding bars 35 located between successive switch units prevent magnetic flux set up in the pole pieces of one unit by means of the flux concentrator arms 26, 28 from fringing over into the space occupied by the ball armature of adjacent units.

For most applications of the invention the permanent magnet 16 (or the face of the intermediate pole 16c contacted by the balls 36) will be grounded, as indicated at 16d. Thus, the effect of energizing the solenoid in one sense or the other to draw a switch contact ball 36 into electrical contact with the upper or the lower pole piece 34 associated therewith will be to ground that pole piece, hence the electrical conductor 40 connected to the outer end thereof.

In the operation of the device, by rotating the shaft 12, hence the flux concentrator arms 26 and 28, successively past the pairs of pole pieces and applying impulses of current to the solenoid 30 of one polarity or the other in timed relation to registry of the flux concentrator's arms with the individual pairs of pole pieces, a selective switching action is achieved. Once a switch contact ball 36 has been actuated into one position or the other, it will remain in that position due to the holding action of the permanent magnet 16, since the upper or lower pole piece 34 then being contacted by that ball becomes an effective extension of the north magnetic pole of the permanent magnet 16. Only by energizing the solenoid 30 with the reverse polarity when the flux concentrator arms 26 and 28 are again in registry with the same pair of pole pieces will the particular switch contact ball 36 be moved into its opposite switching position. The neces-

sary magnetizing force applied by the solenoid 30 to the flux concentrator arms 26 and 28 for shifting the balls 36 in the described manner is not sufficient to change the permanent magnetization of the casing magnet 16.

In the modified form of sequentially operated, multiple unit selective switching device shown in Figure 9 the annular permanent magnet 16' is inside the structure and its magnetic pole flanges 16a, 16b and 16c face outwardly surrounded by the alternately arranged flux shield bars 35' and sets of pole pieces 34'. Moreover, magnetization of the annular permanent magnet structure 16' is derived in this instance by continuous energization of the two annular coils 16'u and 16'p received in the respective annular grooves between the intermediate flange 16'c and the upper and lower flanges 16'a and 16'b. By locating the series of pole pieces and coating ball armatures outside the magnetic structure the over-all diameter of the device may be reduced for a given minimum spacing achieved between successive sets of pole pieces. The coils 16'u and 16'p will be energized with the polarities illustrated in order to produce the desired magnetic polarities of the permanent magnet flanges as magnetic poles.

In either of the forms shown in Figures 5 and 9 the actuating coil of the electromagnet (30 or 30') may be replaced by two coils, if desired, so that erasure can be accomplished by a second coil instead of by reversing the polarity of a single coil.

As in the case of individual relays incorporating the invention (Figure 1, for example) the minor amount of movement required of the switch contact balls 36 to be attracted magnetically from one position to the other in the sequential selective switching operations of the multiple switch unit device is not of such a nature as to produce any appreciable mechanical wear, yet slight wiping action of the balls is inherently produced in each actuation thereof as desired for establishing good electrical contact. Thus the life expectancy of this modified form of the sequential selective switching device is potentially greater than that in which the switch contact elements are not free ferromagnetic balls but are resiliently flexible reeds which must be held by mechanical means such as a rotating barrier member sliding thereon in order to retain them in actuated position throughout a cycle of operation of the device and which after repeated flexures may tend to crystallize or fatigue.

These and other advantages of the construction herein disclosed will be apparent to those skilled in the art. Moreover, it will be apparent that various other arrangements and types of construction of the individual relay version and the multiple switch unit sequential operating version may be produced within the teachings of the invention featuring the combined temporarily magnetizable magnet means and permanent magnet means cooperating with a single ferromagnetic ball armature.

I claim as my invention:

1. A sequential selective switching device comprising a magnetic flux concentrator means, means mounting said flux concentrator means for repetitive movement in a predetermined path, means selectively energizable for magnetizing said flux concentrator means at selected times during movement thereof along said path, a plurality of pairs of magnetic pole members stationed at successive locations along said path for individually sustaining in any such pair the magnetic flux from said magnetic flux concentrator means when the latter is magnetized and substantially in registry with any such magnetic pole member pair, substantially to the exclusion of adjacent magnetic pole members, the members of each such pair of magnetic pole members being separated to form an interpole space therebetween, and at least one of said pole members having an electrically conductive pole face adjoining said space and arranged to function as a switch contact element, permanent magnet means

arranged cooperatively with said pairs of magnetic pole members to form permanent magnetic flux circuits including the respective pole members and including said interpole spaces, said permanent magnet means including an electrically conductive pole face immediately adjoining each of said interpole spaces and arranged to function as a switch contact element cooperatively with said first-mentioned switch contact elements, and a plurality of unattached ferromagnetic armature elements received in the respective interpole spaces for freedom of movement therein to contact simultaneously said permanent magnet pole face and either one of the associated magnetic pole members, each of said armature elements being magnetically attractable from either of the associated magnetic pole members to the other magnetic pole member in accordance with the direction of magnetic flux passing from said flux concentrator member through such magnetic pole members, such armature element having an electrically conductive surface and being retained in position contacting both a magnetic pole member and said permanent magnetic pole face by the permanent magnetic attraction of said permanent magnet means.

2. The device defined in claim 1, wherein the ferromagnetic armature elements comprise round balls of ferromagnetic material having a surface of electrically conductive material.

3. A sequential selective switching device comprising a shaft mounted for rotation, a pair of magnetic flux concentrator arms projecting in like directions from said shaft at locations spaced apart along the length thereof for rotation with said shaft, a solenoid surrounding said shaft and selectively energizable for magnetizing said flux concentrator arms at selected times during rotation thereof, a plurality of pairs of magnetic pole members arranged parallel to the axis of said shaft in positions of alignment of the members of each such pair at successive locations around the rotational path of said arms for individually sustaining in any such pair the magnetic flux from said magnetic flux concentrator arms when the latter are magnetized and substantially in registry with any such magnetic pole member pair, substantially to the exclusion of adjacent magnetic pole members, the members of each such pair of magnetic pole members being separated to form an interpole space therebetween, and at least one of said pole members having an electrically conductive pole face adjoining said space and arranged to function as a switch contact element, permanent magnet means arranged cooperatively with said pairs of magnetic pole members to form permanent magnetic flux circuits including the respective pole members and including said interpole spaces, said permanent magnet means including an electrically conductive pole face immediately adjoining each of said interpole spaces and arranged to function as a switch contact element cooperatively with said first-mentioned switch contact elements, and a plurality of unattached ferromagnetic armature elements received in the respective interpole spaces for freedom of movement therein to contact simultaneously said permanent magnet pole face and either one of the associated magnetic pole members, each of said armature elements being magnetically attractable from either of the associated magnetic pole members to the other magnetic pole member in accordance with the direction of magnetic flux passing from said flux concentrator arms through such magnetic pole members, such armature element having an electrically conductive surface and being retained in position contacting both a magnetic pole member and said permanent magnetic pole face by the permanent magnetic attraction of said permanent magnet means.

4. The device defined in claim 3, wherein the ferromagnetic armature elements comprise round balls of

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ferromagnetic material having a surface of electrically conductive material.

5. The device defined in claim 4, wherein the permanent magnet means comprises a magnetized annular member having three inwardly projecting annular pole elements extending around the inside periphery thereof at mutually spaced-apart locations along the length of said annular member, the two outside pole elements being of like magnetic polarity and opposite to the magnetic polarity of the intermediate pole element, said intermediate pole element being the one adjoining the interpole spaces and having the conductive pole face.

6. Switch means comprising, in combination, a circular series of pairs of magnetic pole elements separated from each other to define interpole spaces between the members of each such pair, annular permanent magnet means surrounding said magnetic pole element series and having an intermediately situated magnetic pole of one polarity with an electrically conductive face adjoining said interpole spaces and further having two additional magnetic poles of a polarity opposite that of said intermediately situated pole adjoining the respective magnetic pole elements of said pairs, thereby to include said respective magnetic pole elements in the two permanent magnetic field circuits existing between said intermediately situated pole and the two additional magnetic poles, a plurality of ferromagnetic balls having electrically conductive surfaces loosely received in the respective interpole spaces and being adapted for simultaneously contacting said intermediately situated pole conductive face and either of the adjoining magnetic pole elements, said latter elements likewise having electrically conductive pole faces engageable by said balls, means forming individual electrical connections to the respective magnetic pole elements as switch contact elements cooperative with said intermediately situated magnetic pole conductive face as a common switch contact element, and selectively energizable magnetizing means operable to scan said magnetic pole element pairs in successive order and selectively magnetize the same temporarily with flux of one direction or the other passed through the associated interpole spaces and thereby move the ferromagnetic balls from one magnetic pole element to the other depending on such flux direction.

7. The switch means defined in claim 6, wherein the magnetizing means comprises a pair of ferromagnetic flux concentrator arms, a ferromagnetic shaft supporting such arms for rotating inside the circular series of magnetic pole element pairs, and selectively energizable solenoid means surrounding said shaft for magnetizing the same, hence said arms and magnetic pole elements instantaneously adjacent said arms, by passage of current through said solenoid means.

8. Switch means comprising, in combination, a circular series of pairs of magnetic pole elements separated from each other to define interpole spaces between the members of each pair, annular permanent magnet means arranged concentrically within said circular series of pairs of pole elements and having outwardly facing intermediately situated magnetic pole means of one polarity with an electrically conductive face adjoining said interpole spaces and further having two additional magnetic poles of a polarity opposite that of said intermediately situated pole adjoining the respective magnetic pole elements of said pairs, thereby to include said respective magnetic pole elements in the two permanent magnetic field circuits existing between said intermediately situated pole and the two additional magnetic poles, a plurality of ferromagnetic balls having electrically conductive surfaces loosely received in the respective interpole spaces and adapted for simultaneously contacting said intermediately situated pole conductive face either of the adjoining magnetic pole elements, said latter elements likewise having electrically conductive pole faces engageable by said balls,

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means forming individual electrical connections to the respective magnetic pole elements as switch contact elements cooperative with said intermediately situated magnetic pole conductive face as a common switch contact element, and selectively energizable magnetizing means operable to scan said magnetic pole element pairs in successive order and selectively magnetize the same temporarily with flux of one direction or the other passed through the associated interpole spaces and thereby move the ferromagnetic balls from one magnetic pole element to the other depending on such flux direction.

9. Switch means comprising, in combination, a circular series of pairs of magnetic pole elements separated from each other to define interpole spaces between the members of each pair, a series of magnetic flux shielding elements interposed between respectively adjacent pairs of magnetic pole elements, annular permanent magnet means arranged concentrically with respect to said circular series of pairs of pole elements and having intermediately situated magnetic pole means of one polarity with an electrically conductive face adjoining said interpole spaces and further having two additional magnetic poles of a polarity opposite that of said intermediately situated pole adjoining the respective magnetic pole elements of said pairs, thereby to include said respective magnetic pole elements in the two permanent magnetic field circuits existing between said intermediately situated pole and the two additional magnetic poles, a plurality of ferromagnetic balls having electrically conductive surfaces loosely received in the respective interpole spaces and adapted for simultaneously contacting said intermediately situated pole conductive face either of the adjoining magnetic pole elements, said latter elements likewise having electrically conductive pole faces engageable by said balls, means forming individual electrical connections to the respective magnetic pole elements as switch contact elements cooperative with said intermediately situated magnetic pole conductive face as a common switch contact element, and selectively energizable magnetizing means operable to scan said magnetic pole element pairs in successive order and selectively magnetize the same temporarily with flux of one direction or the other passed through the associated interpole spaces and thereby move the ferromagnetic balls from one magnetic pole element to the other depending on such flux direction.

10. Selective switching apparatus comprising a first electrical contact surface, a ferromagnetic ball occupying a region adjacent said surface, permanent magnet means passing magnetic flux through said surface and said ball to attract said ball against said surface, two additional surfaces at least one of which comprises an electrical contact surface adjoining said region and disposed generally perpendicular to said first surface, on opposite sides of said ball at a relative spacing permitting contact of said ball with only one of said additional surfaces at a time, two ferromagnetic elements defining magnetic flux paths contiguous to said two additional surfaces, respectively, and arranged to pass said permanent magnetic flux and electromagnet means energizable for passing magnetic flux through said additional surfaces and said region in either of opposite senses to make either of said additional surfaces a north magnetic pole and the other a south magnetic pole depending on the polarity of energization of said permanent magnet means, thereby drawing said ball magnetically into contact with one or the other of said two surfaces to be held in contact therewith by said permanent magnet flux, said permanent magnet means comprising two permanent magnet elements contiguous to the said two additional surfaces, respectively, and the electromagnet means comprising a ferromagnetic core element contiguous to the first-mentioned surface and forming a magnetic flux path common to said permanent magnet elements.

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