

United States Patent

[11] 3,594,785

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| [45] | Patented | July 20, 1971 |
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|-----------|---------|---------------|------------|
| 3,260,871 | 7/1966 | Lang | 340/378 |
| 3,482,126 | 12/1969 | Bradley | 340/378 |
| 3,492,615 | 1/1970 | Watkins | 340/378 MW |

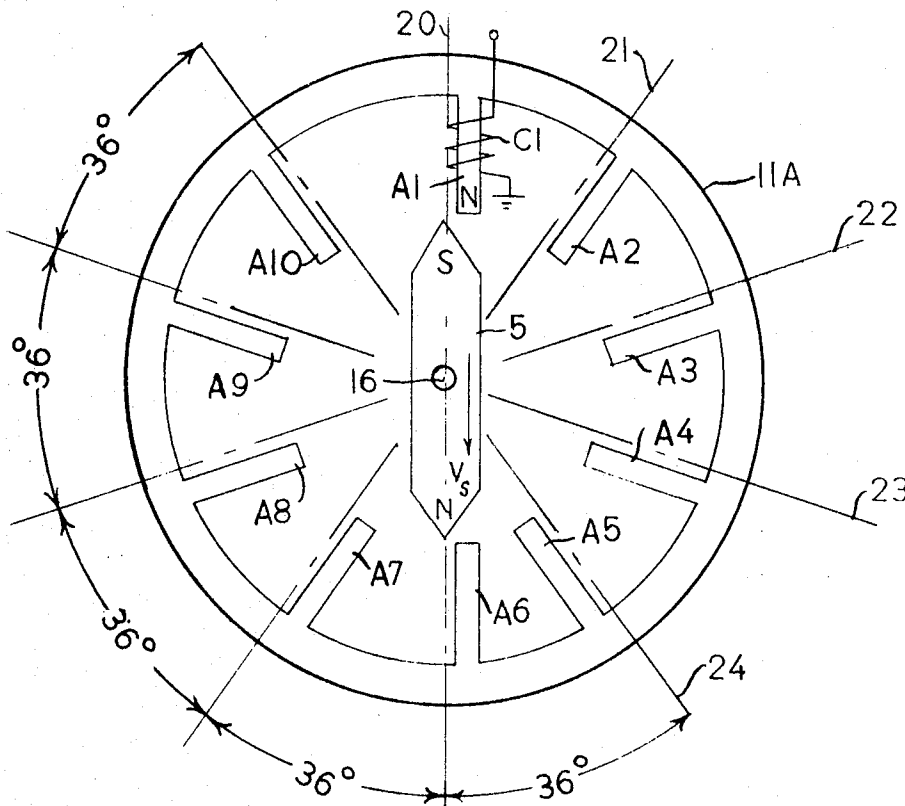
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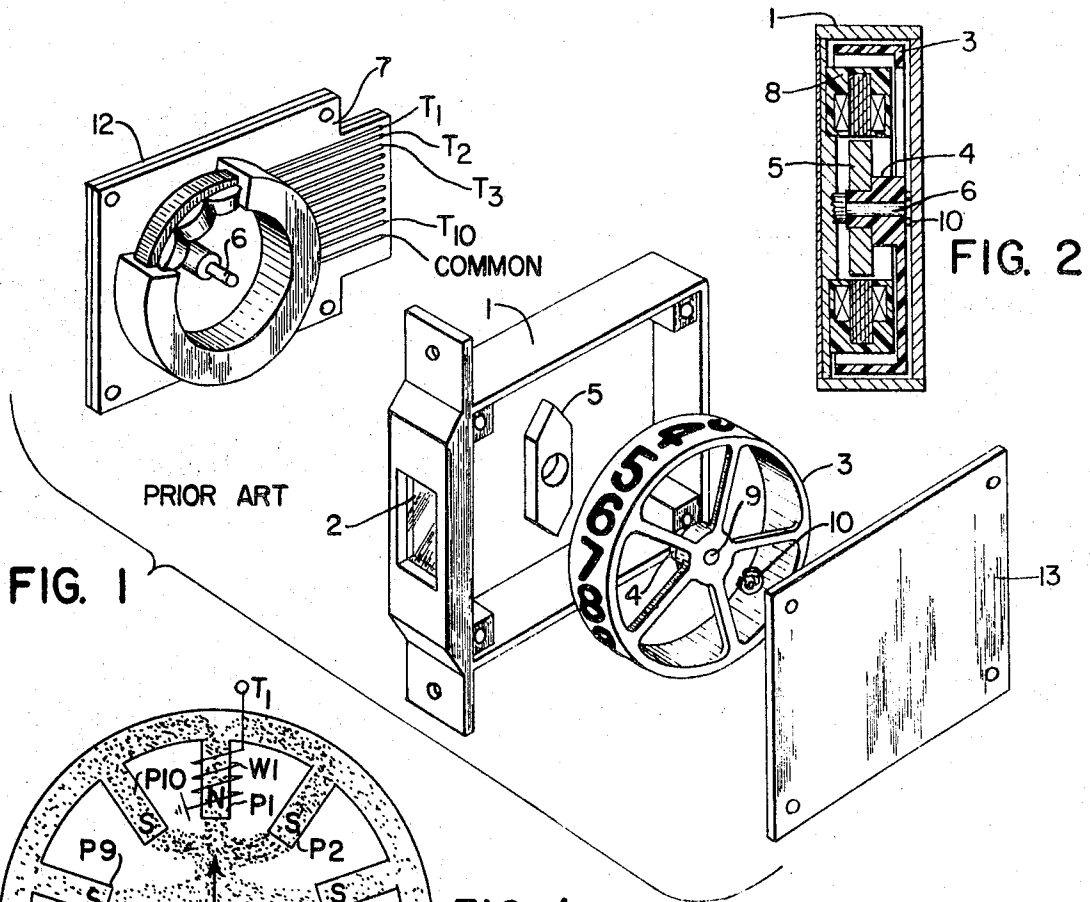
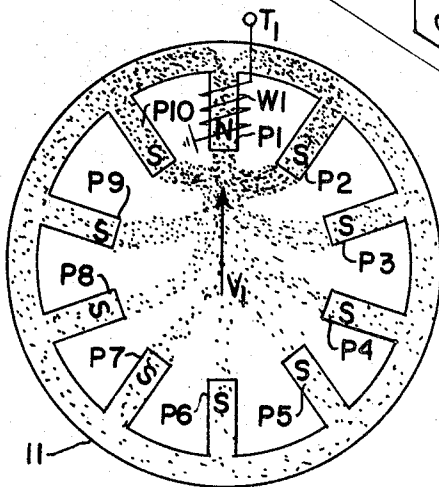
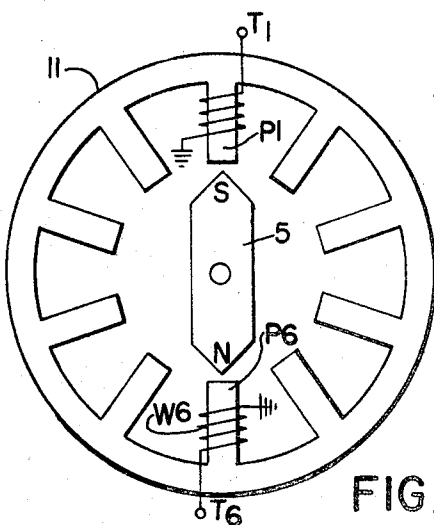
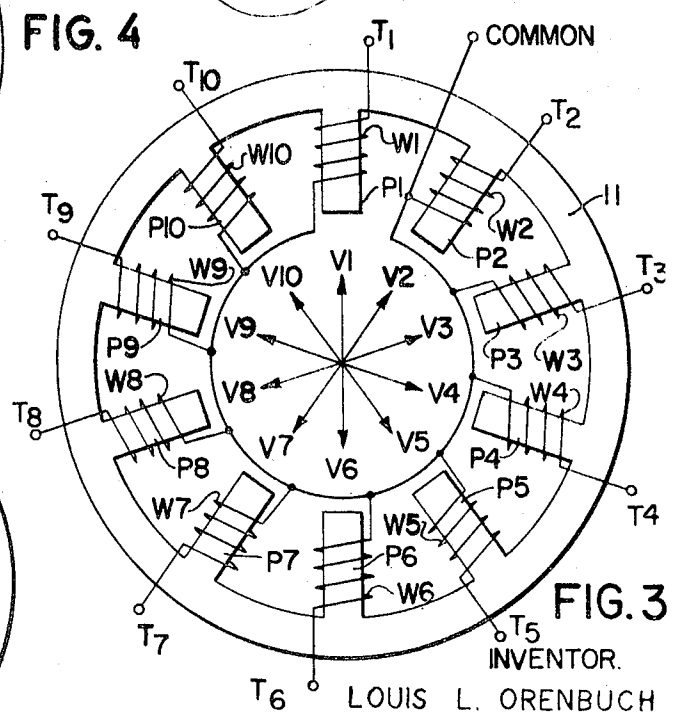
- [54] ELECTROMAGNETIC INDICATOR HAVING
ASYMMETRICALLY POLED STATOR
3 Claims, 7 Drawing Figs.**

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| [52] | U.S. Cl..... | 340/378 R,
310/49 R, 335/281 |
| [51] | Int. Cl..... | G08b 5/24 |
| [50] | Field of Search..... | 340/373,
378, 378 MW; 310/46, 49, 254, 258, 259;
335/268, 272, 281 |

- [56] **References Cited**
UNITED STATES PATENTS
3,118,138 1/1964 Milas.....

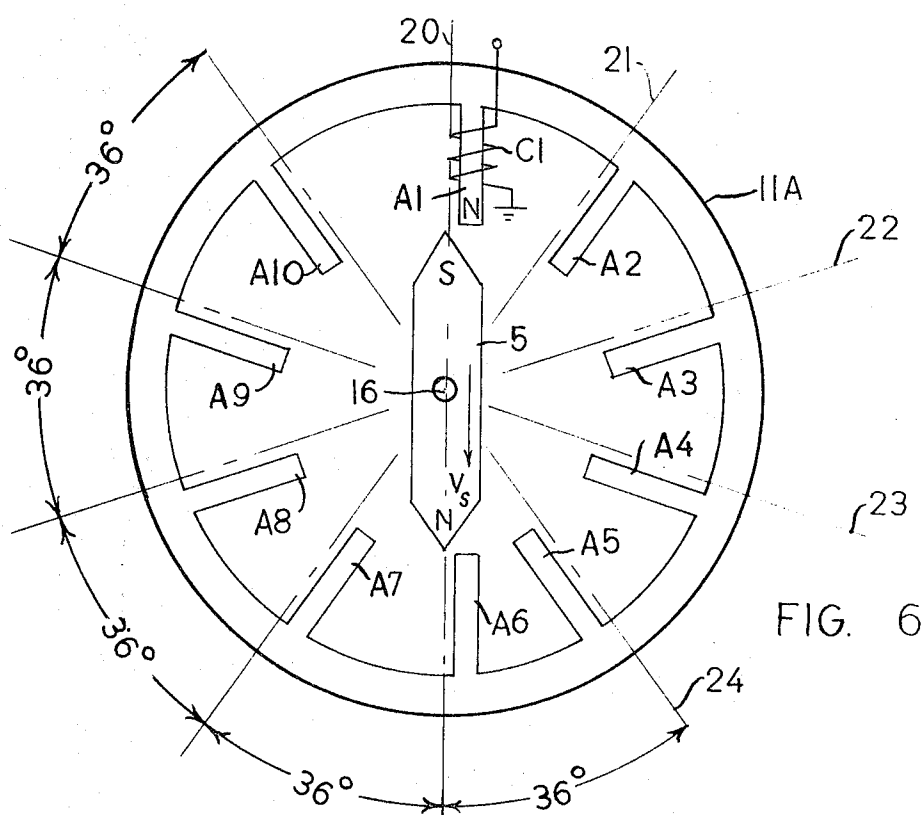
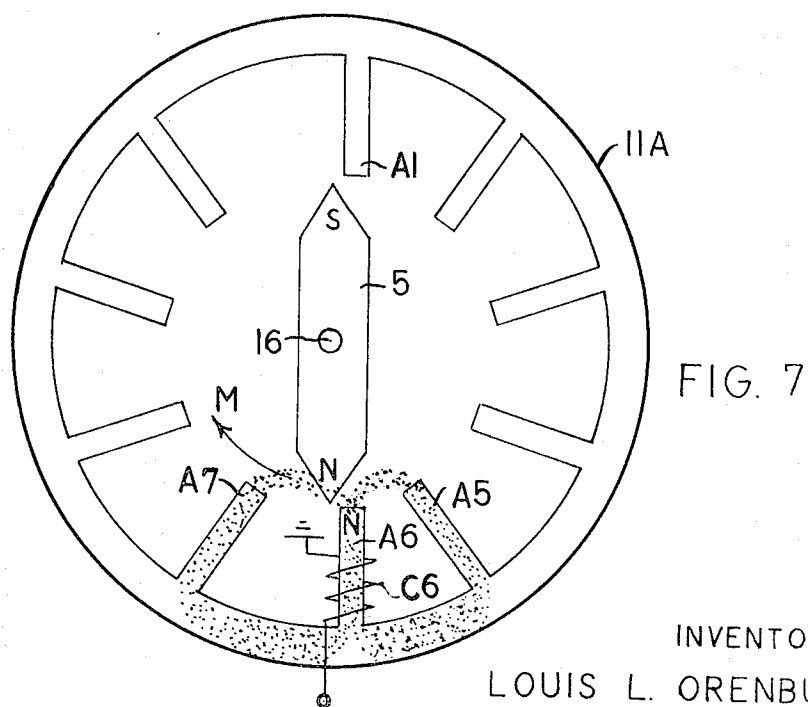
ABSTRACT: An indicator is disclosed having a rotor which is able to turn promptly to 180° opposed positions to permit the successive display of diametrically opposed symbols carried on a drum. The position of the rotor drum is governed by a stator having poles projecting inwardly from an annular core. Windings on the poles are arranged to permit the stator to establish any one of a number of differently oriented magnetic fields. The rotor has a permanent magnet which rotates about an axis at the geometric center of the annular core to align itself with the stator's magnetic field. The poles of the stator are arranged on the annular core in pairs which are not diametrically opposed but are aligned to cause the vector representing the stator's field to be parallel to and offset from the aligned position taken by the permanent magnet.





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ELECTROMAGNETIC INDICATOR HAVING ASYMMETRICALLY POLED STATOR

FIELD OF THE INVENTION

This invention relates in general to indicators of the type having symbols marked upon the drum of a rotor that can turn to bring any of the symbols into a display station. More particularly, the invention pertains to indicators in which the orientation of the rotor is governed by an electromagnetic stator that can be energized by electric signals to establish any one of a plurality of discretely oriented magnetic fields. The invention is concerned with indicators in which the rotor must be able to assume 180° opposed positions to permit diametrically opposed symbols on the drum to be displayed in succession. In such electromagnetic indicators, it is usual to employ symbols, such as arabic numerals or alphabetic characters, that are of uniform height. To permit the symbols to be of maximum size, the symbols are spaced at regular intervals around the drum's periphery. Where there are an even number of symbols, each symbol is diametrically opposite another symbol. That arrangement utilizes the peripheral surface area of the drum as fully as possible, but requires that the drum be capable of turning to a 180° opposite position where diametrically opposed symbols are displayed in succession. The invention insures the application of a turning force on the rotor whenever the rotor is required to assume a 180° opposite position.

DISCUSSION OF THE PRIOR ART

In electromagnetic indicators of the type here considered, the drum is part of a rotor having a permanent magnet and the orientation of the rotor is governed by the electromagnetic stator which is capable of establishing any one of a plurality of discretely oriented magnetic fields. For each symbol on the drum, there is a uniquely oriented magnetic field that can be established by the stator in response to electrical "command" signals. The establishment by the stator of a discretely oriented magnetic field constrains the rotor to turn and align its permanent magnet with the stator's magnetic field. The symbol bearing drum is fixed to the permanent magnet and, when the magnet is aligned with the stator's field, a symbol is in register in the display station. Usually the display station is a window in a structure which permits only one drum symbol at a time to be visible in its entirety. The rotor, in prior art indicators, tends to "hangup" when it is next required to display the diametrically opposite symbol. That is, the rotor initially tends to move sluggishly or not at all when it is commanded to turn to the 180° opposite position.

To avoid hangup of the rotor, prior art indicators are provided with "offset" as taught by U.S. Pat. Nos. 2,943,313; 3,311,911; and 3,392,382. The use of "offset" requires that the permanent magnet first align itself with the stator's magnetic field and then move to an offset position when the stator's magnetic field decays upon cessation of the stator's energizing electrical signal. The use of "offset" is inherently effective in avoiding hangup of the rotor in the "intermittent" mode of operation because the stator's magnetic field, in the interval between intermittent signals, collapses to permit the rotor to move to its offset position. In the intermittent mode of operation, the "command" signals are electrical pulses which are applied to the stator for the interval needed to cause the rotor to move to its next station and the "command" signals are not present during the display interval. In continuous mode operation, the stator is almost continuously electrically energized as the termination of a subsisting signal is rapidly followed by another electrical signal. The use of "offset" is not effective in the continuous mode of operation unless sufficient time is allotted between successive command signals to permit the rotor to move to its offset position in the interval between these signals.

An indicator having "offset" is characterized by a "blink" of the symbol in the window. The blink occurs when the rotor

turns from its field aligned position to its offset position. The "blink" of prior art indicators is an undesired characteristic. Efforts have been made to provide a nonblinking indicator in which the rotor does not hangup when 180° rotation is required. For example, U.S. Pat. No. 3,419,858 discloses an indicator employing magnetizable pins on the rotor to assure a turning moment on the rotor. For economic and technical reasons, it is usually undesirable to complicate the relatively simple and symmetrical structure of the rotor by placing pins or other elements on the rotor. For rapid indicator operation with low power requirements, the mass of the rotor must be kept small to maintain its inertia at a minimum. Further, unless the added elements are carefully disposed in regular fashion about the rotor, the added elements tend to upset the balance of the rotor and cause poor registration of the symbols in the window of the indicator. The invention here disclosed achieves its objectives without requiring additions or alterations in the simple symmetrical rotor.

OBJECTIVES OF THE INVENTION

This invention concerns electromagnetic indicators of the type having a rotor employing a symbol bearing a drum whose position is magnetically governed and whose operation requires the rotor to assume, in succession, 180° opposite positions. The principal objective of the invention is to provide an indicator in which the presence of a turning force on the rotor is assured whenever the rotor is required to turn to a 180° opposite position. A further objective of the invention is to assure the presence of that turning force in a nonblinking indicator that can operate in both the intermittent and continuous modes.

THE DRAWINGS

The invention, both as to its construction and its manner of operation, can be better understood from the following exposition when it is considered in conjunction with the accompanying drawings in which:

FIG. 1 is an exploded view of a conventional electromagnetic indicator having a rotor which turns in response to the discretely oriented magnetic field established by the stator to display one of the ten arabic numerals inscribed on the drum;

FIG. 2 is a cross-sectional view of the assembled conventional indicator and shows the arrangement of the components within the housing;

FIG. 3 schematically represents the stator employed in the FIG. 1 indicator and depicts the circular array of poles which protrude radially inwardly from the annular ferromagnetic core;

FIG. 4 depicts the flux pattern of the magnetic field established by energizing a winding of the conventional radial pole stator;

FIG. 5 illustrates the alignment of the rotor's permanent magnet with the field of the electrically energized radial pole stator;

FIG. 6 schematically depicts a stator having inwardly protruding poles arranged in accordance with the invention to insure the exertion of a turning force upon the permanent magnet when the rotor is required to turn to the 180° opposite station; and

FIG. 7 illustrates the operation of the invention when a signal is applied to the stator to cause the rotor to turn to the 180° opposite station.

THE EXPOSITION

FIG. 1 depicts an indicator of conventional construction employing a housing 1 having a front panel containing a window 2 for displaying symbols marked upon the periphery of a drum 3. The drum has a hub 4 to which a permanent magnet 5 is secured, as shown in the sectional view of FIG. 2. The drum and permanent magnet comprise a rotor that is mounted to turn as a unit about a shaft 6. The shaft is secured to a board 7 and extends through the center of an annular stator 8. The hub

4 has a central bore 9 which permits the rotor to be mounted on the shaft. To retain the rotor so that it cannot slip off the shaft, a groove is provided near the shaft's end and the groove is engaged by a C-shaped lock member 10.

In the conventional indicator, the permanent magnet is symmetrical in shape because a symmetrical form tends to insure the balance of the rotor. That is, the rotor is usually finely balanced to turn freely upon the shaft and a symmetrical form conduces to that result. The permanent magnet may be of the bar shape shown in FIG. 1 or the magnet may have some other symmetrical shape such as oval or round. Whatever the form, in the conventional indicator, the magnetic poles of the permanent magnet are 180° apart with respect to the magnet's axis of rotation.

The stator 8, schematically depicted in FIG. 3, has an annular ferromagnetic core 11 from which 10 poles P1, P2—P10 protrude radially inward. The core and radial poles are preferably formed as an integral unit by blanking the core and radial poles from a sheet of ferromagnetic material. As blanking operations are usually restricted to relatively thin sheet stock, a number of identical blanked forms are assembled in alignment to provide a core of the desired thickness. The poles are identical and are arranged symmetrically around the annulus so that each pole is diametrically opposite another pole. Each of the 10 poles is surrounded by its own winding, symbolically indicated in FIG. 3 by the windings W1, W2—W10. The windings are arranged to permit each of them to be separately energized by applying an electrical signal to it. Conventionally each winding has one end connected to a COMMON line and the electrical signals applied at the input terminals T1, T2—T10 to the windings are all of the same polarity with respect to the COMMON potential.

The stator 8 has its core 11 and windings embedded in a matrix of a synthetic resin (viz, a "plastic" substance). In FIG. 1 a portion of the matrix is broken away to show the ferromagnetic core and some of the windings. The synthetic resin holds the windings fixed upon the radial poles and facilitates securing the stator upon the circuit board 7. In FIG. 3, the stator is shown without its plastic embedment.

The stator is secured to the board 7 which has electrical conductors to which windings W1, W2—W10 are connected. By applying an electrical signal to one of the terminals T1, T2—T10 and the COMMON terminal, a selected one of the windings can be electrically excited to establish a magnetic field.

As indicated in the sectional view of FIG. 2, the stator and rotor fit within the housing 1. In the assembled device, the drum 3 surrounds the annular stator 8 and the permanent magnet of the rotor is in the same plane as the radial poles of the stator. The sides of housing 1 are closed by end plates 12 and 13 which act as magnetic shields to prevent extraneous magnetic fields from interfering with the operation of the indicator. At the corners of the housing, posts are provided to receive the screws or other fastening devices which hold the end plates securely to the housing. In the assembled indicator, the circuit board 7 protrudes from the rear of the housing to permit access to terminals T1, T2—T10 and COMMON.

Assuming the stator is isolated in air or in a vacuum and that winding W1 of the stator is electrically energized to cause pole P1 to be a North magnetic pole, all the other poles, as shown in FIG. 4, become South magnetic poles. The flux pattern of the magnetic field established by the energized winding is indicated by the stippling in FIG. 4. The flux tends to take the path of least reluctance and therefore, the smaller the gap between the North and South magnetic poles, the greater is the flux intensity. Conversely, the magnetic flux is least intense where the gap is the longest. Consequently, the flux emanating from the North magnetic pole P1 tends to divide and extend principally to the nearer South magnetic poles with little of the flux reaching the most distant South magnetic pole P6. The magnetic field is represented in FIG. 4 by the vector V1 whose direction is toward the North magnetic pole and whose length is a measure of the magnetic field intensity.

The line of action of vector V1, it should be observed, extends through the geometric center of the annular core 11 and centrally through pole P1. Permanent magnet 5 which is within the magnetic field, rotates about shaft 6 into alignment with the vector V1 and assumes the position depicted in FIG. 5 where the South pole of the permanent magnet is adjacent to pole P1 and the other pole of the permanent magnet is adjacent to pole P6. With the magnet aligned, as indicated in FIG. 5, with the vector V1, one of the symbols on the drum is positioned in the window 2 of the housing.

By separately energizing each of the stator windings, 10 discretely oriented magnetic field vectors V1, V2—V10 can be established as indicated in FIG. 3 and thereby any one of 10 symbols on the drum can be brought into display position in the window of the housing. Each symbol on the drum is of such size that it completely fills the window so that only one symbol can be in registration with the window at any time. For the purpose of exposition, the symbols are assumed to be the arabic numerals 0, 1, 2—9 and it is assumed that the display of numeral 1 is governed by the vector V1, the display of numeral 2 is governed by vector V2, the display of numeral 3 is governed by vector V3, and so on. It is evident from FIG. 3 that each of the vectors has its line of action extending through the geometric center of the annular core and that each vector is in line with a vector extending in the 180° opposite direction. Because of that vectorial arrangement, the numerals on the drum are disposed so that each numeral is diametrically opposite to another numeral on the drum.

Assuming the permanent magnet has rotated into alignment with poles P1 and P6, as indicated in FIG. 5, and that the electrical excitation of winding W1 ends, the magnetic field established by the stator collapses. The rotor, however, retains its aligned position because of the attractive force between the poles of the permanent magnet and the adjacent radial poles P1 and P6 of the stator. The indicator, in essence, then has a "memory" because the rotor remains in position after the input signal to the stator has ended and retains that position until the rotor is commanded to take another position by energizing a different winding on the stator. In the interval between the application of "command" signals, the stator is electrically unenergized. That mode of operation is the intermittent mode.

In the continuous mode of operation, an electrical signal is applied to winding W1, for example, during the entire period that the numeral 1 is to be displayed. When another symbol is to be displayed, the electrical signal to winding W1 is immediately succeeded by the application of an electrical signal of the same polarity to some other winding of the stator. For example, where the display of numeral 1 is to be succeeded by the display of the numeral 6, the signal applied to winding W1 is terminated and the winding W6 is then energized by an electrical signal applied at terminal T6. The rotor which was originally aligned as indicated in FIG. 5, must then turn through 180° to align itself with the V6 vector. In the conventional indicator, there is no turning moment present to cause the rotor to turn because the resultant force acting on the permanent magnet is directed through the rotor's axis of rotation. That is, the forces of repulsion exerted on the permanent magnet's poles when winding W6 is electrically energized, are directed through the axis of rotation so that no unbalanced couple arises. The rotor, consequently, tends to remain in position (viz, tends to "hangup") and its initial turning motion, if it turns at all, is sluggish. Where consistently rapid operation of the indicator is desired, the tendency of the rotor to hangup when it is commanded to turn to a 180° opposite position is a disadvantage in conventional indicators which is present in both modes of operation.

FIG. 6 schematically depicts an embodiment of the invention that is an improvement upon the previously described conventional indicator. The rotational axis 16 of the permanent magnet 5, in the FIG. 6 embodiment, is at the geometric center of the annular ferromagnetic core 11A and therefore is coincident with the post 6. The embodiment depicted

in FIG. 6 differs from the conventional indicator principally in the disposition of the poles A1 to A10 around the annular ferromagnetic core. The poles A1 to A10 are arranged in pairs having aligned longitudinal axes. The pole A6, for example, is aligned longitudinally with the A1 pole. Although aligned, the poles A1 and A6 are not diametrically opposed with respect to the annular core but rather are offset so as not to extend radially inwardly.

For ease of exposition, it is convenient to consider the annular ferromagnetic core as being partitioned into segments by diametral lines, as indicated in FIG. 6. Each pair of poles governs the display of two symbols situated diametrically opposite on the indicator's drum. For the indicator to be capable of displaying the 10 decimal numerals, the stator must have five pairs of poles. Assuming that the 10 symbols are regularly spaced around the drum, the annular core 11A is partitioned by five diametral lines 20, 21, 22, 23, 24, angularly spaced at 36° intervals. The poles which protrude from core 11A can then be considered to be arranged in pairs with respect to those diametral lines. The stator poles A1 and A6 constitute a pair that extend inwardly parallel to diametral line 20. Both of those poles, as viewed in FIG. 6, are equally offset to the right with respect to diametral line 20 so that the axes of the poles are longitudinally aligned. The other stator poles are similarly situated with respect to diametral lines 21, 22, 23, and 24.

The arrangement of windings on stator poles A1 through A10 need not differ from the scheme shown in FIG. 3 and while only winding C1 is schematically depicted in FIG. 6, it should be understood that each of the stator poles A1 through A10 is surrounded by its own winding which can be separately electrically energized.

Upon energization of winding C1 to cause pole A1 to be North magnetic, permanent magnet 5 rotates into the position depicted in FIG. 6, where the magnet's South and North poles are adjacent to the inner ends of stator poles A1 and A6. The magnetic flux from pole A1 is coupled through permanent magnet 5 to pole A6. The poles A2, A3, A4, A5, A7, A8, A9, and A10 are virtually excluded from the magnetic flux path by the easier path provided by the permanent magnet. In that circumstance, the magnetic field extending between pole A1 and A6 can be represented by a magnetic field vector V_s , as shown in FIG. 6, which is offset but parallel to diametral line 20. It is important to note that the line of action of vector V_s does not pass through the rotational axis 16 of the magnet 5. If the signal to winding C1 is terminated and no other signal is applied to the stator windings, the rotor remains stationary because that station offers the path of least reluctance for the magnetic flux of the permanent magnet. That is, the stationary position of the permanent magnet depicted in FIG. 6 provides the path of least reluctance for the magnetic flux of the stator when winding C1 is electrically energized as well as the path of least reluctance for the permanent magnet when the stator's windings are electrically unenergized. Therefore, upon electrical deenergization of the stator, the permanent magnet remains at the station where it was aligned parallel to the vector V_s . The indicator thereby has a memory because the last symbol to be displayed continues to be displayed although the command signal to the stator is discontinued. To change the display, the indicator must be commanded to display another symbol by applying an electrical signal to the stator.

Assuming that winding C6 is next energized by an electrical signal to cause pole A6 to become North magnetic, magnet 5 is constrained to immediately rotate and turns to 180° opposite position. A turning force is exerted on the permanent magnet immediately upon the energization of winding C6. The momentary configuration of the magnetic field that arises upon energization of winding C6 is depicted by the stippling in FIG. 7. The magnetic flux path is principally between North magnetic pole A6 and the nearest South magnet poles A5 and A7. The permanent magnet 5, in its original position, is a path of high reluctance which acts to uncouple pole A1 from pole A6. The North pole of magnet 5, due to its disaligned position relative to pole A6 is, consequently, propelled in the

clockwise direction as indicated by the arrow M in FIG. 7. Upon rotating through 180°, the permanent magnet's poles are again adjacent to stator poles A6 and A1 and the flux path of least reluctance is again through the permanent magnet. The magnet then comes to a stop in the station where it most efficiently couples the flux from pole A6 to pole A1.

The permanent magnet is shown in the drawings to be a bar magnet having wedge-shaped ends. The wedge-shaped ends tend to concentrate the magnetic flux of the permanent magnet at two sharply defined magnetic poles. The magnet in effect has salient magnetic poles. The permanent magnet can have other forms as it is not essential to the operation of the indicator that the permanent magnet be of bar shape. However, the permanent magnet, whatever its shape, preferably has its magnetic flux concentrated at two sharply defined magnetic poles. For simplicity of manufacture, a symmetrically shaped magnet having 180° opposite North and South magnetic poles is convenient. Of course, where the magnetic poles of the permanent magnet are not 180° opposed, the location of poles A1, A2—A10 on the stator can readily be adjusted to compensate each pair of poles for the difference.

In the arrangement illustrated in FIGS. 6 and 7, the poles of the stator are not uniformly spaced apart around the annular core because pole A6 is not situated midway between poles A5 and A7, nor is pole A1 situated midway between poles A10 and A2. In indicators of small size, it is desirable to have uniform spacing between the stator poles to permit the windings to be efficiently disposed about each stator pole. To reduce the differences in spacing among the poles of the stator, the poles need but be slightly displaced with respect to the diametral lines 20, 21—24.

Operation of the indicator is enhanced by having small gaps between the salient poles of the permanent magnet and the adjacent poles of the stator when the magnet is in an "aligned" station, as in FIG. 6. For example, the combined airgaps between poles A1 and A6 and the adjacent salient poles of permanent magnet 5 is made small compared to the separation between poles A1 and A2 or compared to the separation between poles A6 and A5. By making those air gaps small, the intermittent mode of operation of the indicator is promoted through the enhanced ability of the permanent magnet to maintain its station when the stator is electrically deenergized. In the "aligned" station shown in FIG. 6, the airgaps between the ends of the permanent magnet and the poles A1 and A6 are equal to prevent one or the other of poles A1 and A6 from having more attraction for the permanent magnet when the stator is electrically unenergized.

In the preferred embodiment of the invention, all the poles A1 through A10 have equal inward protrusions and are equally offset relative to their diametral reference line 20, 21, 22, 23 or 24. Further a pivoted permanent magnet is employed whose salient poles are equidistant from the rotational axis 16. By that arrangement, the amount of retentive force holding the rotor in a fixed station when the stator is electrically deenergized is the same for every station.

Because the invention may be embodied in varied structures, it is not intended that the patent be limited to the forms here illustrated or described. Rather it is intended that the patent be construed to embrace those structures which, in essence, utilize the invention defined in the appended claims.

I claim:

1. In an electromagnetic indicator of the type utilizing a stator having a plurality of poles protruding inwardly from an annular ferromagnetic core, the stator having windings arranged about the poles whereby the stator is capable of establishing any one of a plurality of discretely oriented magnetic fields by selective electrical energization of the windings, and

a rotor having a magnet secured to a drum, the rotor being mounted to cause the magnet to pivot about an axis at the geometric center of the annular core whereby the magnet is constrained by the stator's field to turn to a station providing the path of least reluctance between two poles of the stator,

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the improvement for assuring the presence of a turning force on the magnet whenever the rotor is required to turn to a 180° opposite station, the improvement residing in the arrangement of poles on the stator wherein the plurality of inwardly protruding poles are disposed in aligned pairs, and each pair of aligned poles extends inwardly from the annular core parallel to and offset from a diametral line.

2. In an electromagnetic indicator of the type according to claim 1 which is further characterized in that each inwardly protruding pole of the stator is surrounded by a winding that can be individually electrically energized, and

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the rotor magnet has diametrically opposed magnetic poles, which are equidistant from the axis of rotation the improvement according to claim 1, wherein the inward protrusion of the poles of an aligned pair are equal.

3. In an electromagnetic indicator having the improvement according to claim 1, the improvement further residing in disposing the aligned pole pairs about the annular stator whereby the diametral lines to which the pole pairs are parallel are uniformly angularly spaced around a full circle.

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