

Dec. 15, 1942.

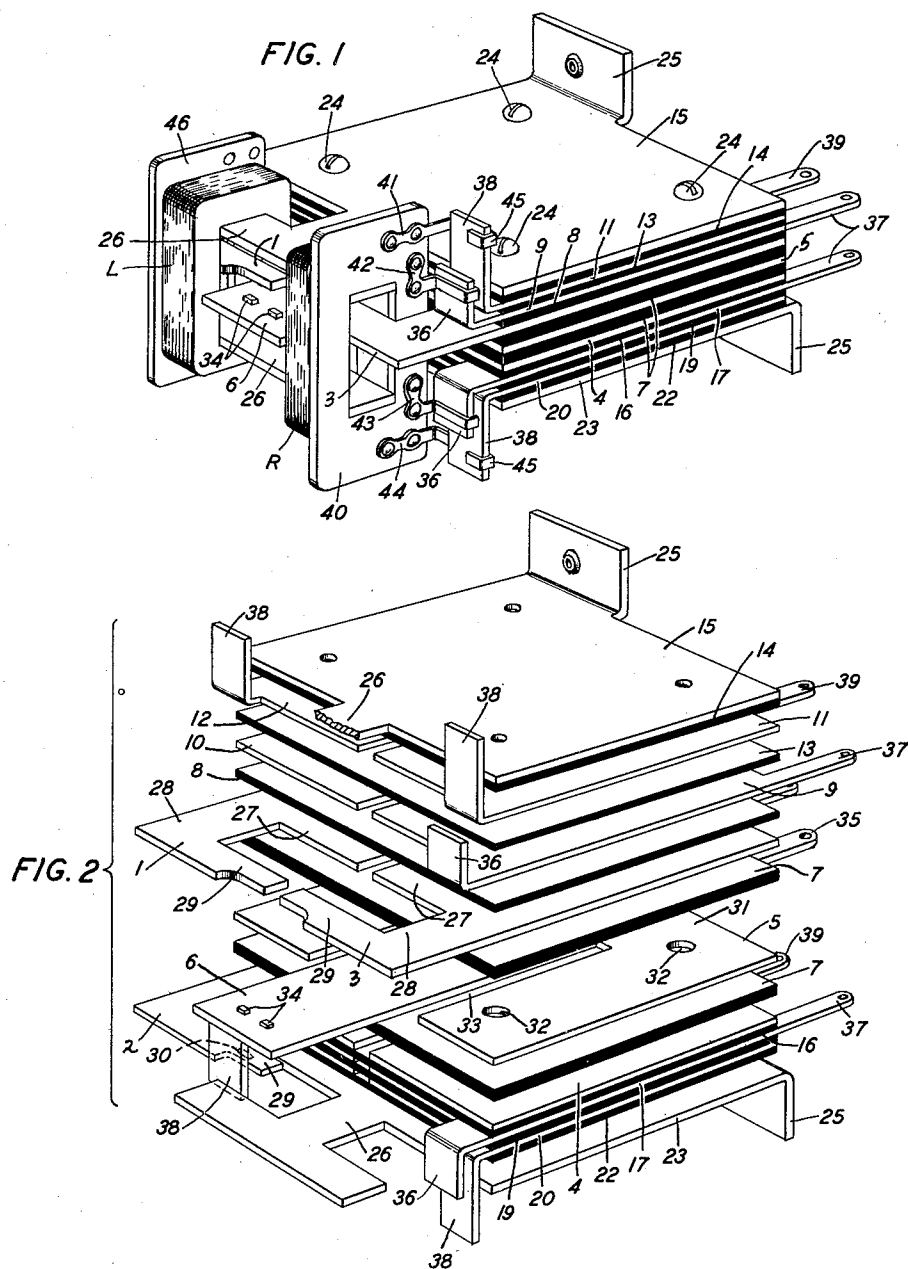
G. R. STIBITZ

2,305,450

RELAY

Filed April 19, 1941

3 Sheets-Sheet 1



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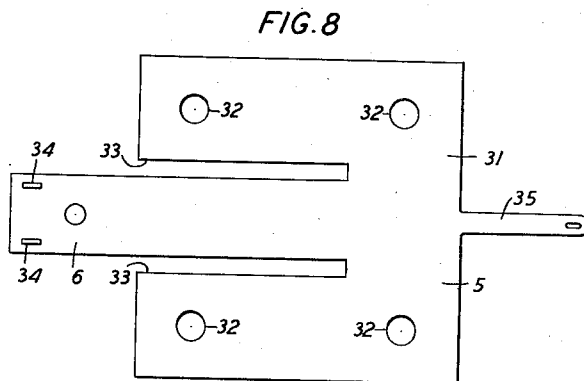
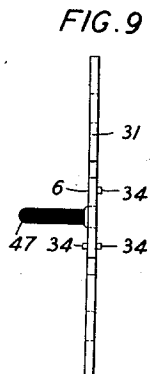
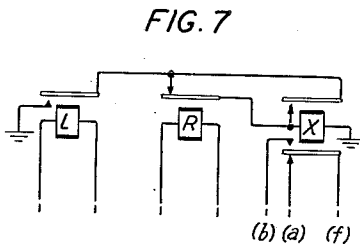
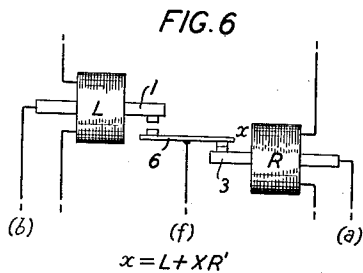
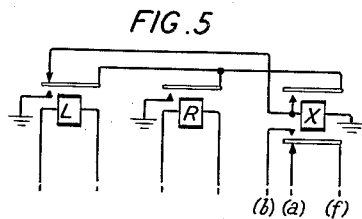
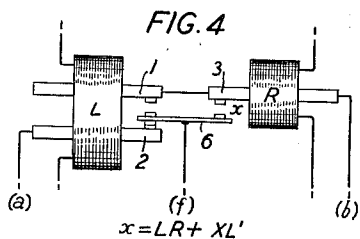
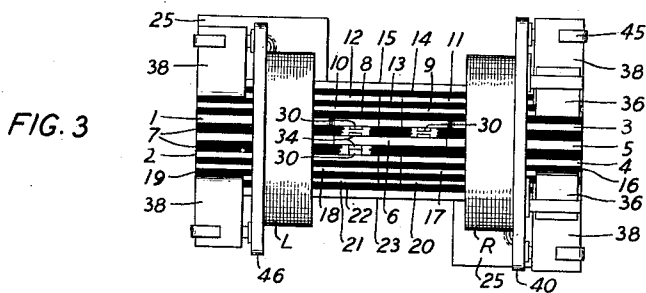
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3 Sheets-Sheet 2



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RELAY

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3 Sheets-Sheet 3

FIG. 12

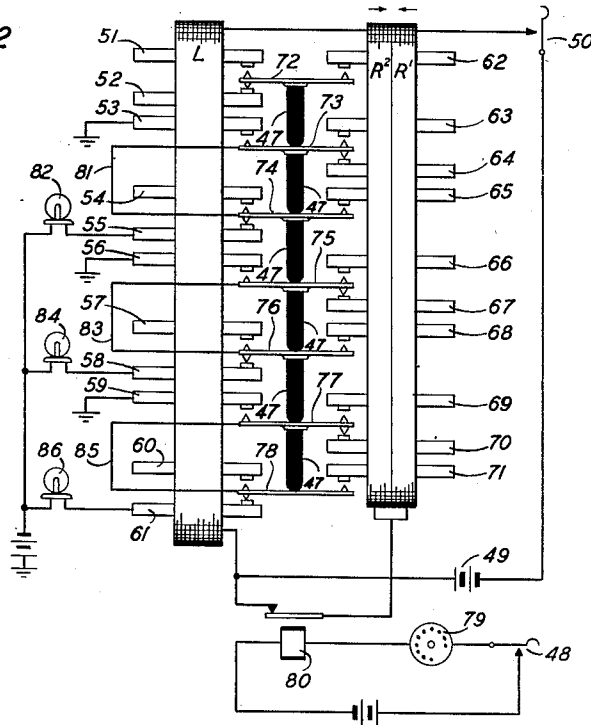
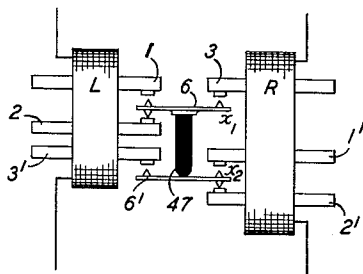


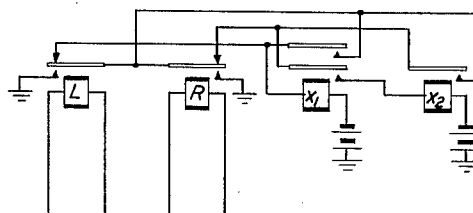
FIG. 10



$$x_1 = LR + L'X_1$$

$$x_2 = LR + X_1 - R'X_2$$

FIG. 11



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UNITED STATES PATENT OFFICE

2,305,450

RELAY

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Application April 19, 1941, Serial No. 389,322

12 Claims. (Cl. 177—353)

This invention relates to switching devices and more particularly to relays each capable of performing the functions of a plurality of relays of the usual type.

The relay structure disclosed in the application of C. N. Hickman and E. Lakatos, Serial No. 367,338, filed November 27, 1940, is provided with a plurality of magnetic circuit units each comprising a fixed field lamination and an armature lamination having a reed armature portion attractable into conductive engagement with the associated field lamination. Since the reed armatures of all of the units of the relay are encircled by a single operating coil, the energization of such coil causes the attraction of all of the reed armatures to their associated field laminations, thus closing a plurality of work circuits. The applicant has discovered that by a rearrangement of the laminations of a relay of this type and by the provision of two energizing coils, the relay may become a radically different device with no equivalent among relays of the well-known conventional types. It can be made to take the place of two conventional non-polarized relays and by combining the magnetic paths of the relay, a single reed armature can be made to take the place of several springs on separate relays. Furthermore, because the functionally independent reed armatures are mounted adjacent to each other in close proximity they may be so intercoupled as to enable still further switching functions to be accomplished by a single relay structure.

It is the object of the present invention to provide a relay structure of the type hereinbefore referred to which in a simple manner is enabled to perform the functions of a plurality of relays of the conventional types with consequent savings in cost, mounting space, wiring and maintenance.

This object is attained by grouping the field laminations in two groups, associating an energizing coil with each of such groups and arranging the armature laminations in such a manner that the reed armature portions thereof may be attracted into conductive engagement with associated field laminations of either group. The object of the invention is further attained by attaching studs of insulating material to the reed armatures in such a manner that with all of the armatures in their normal positions, the free end of the stud of each armature just engages against the adjacent face of the adjacent armature whereby an interaction between the armatures is secured. As a simple example of the adaptability of the invention, a relay may comprise a single armature lamination and three field laminations, two in one group energizable by one energizing coil and located one above and the other below the armature lamination and the third field lam-

ination in a second group and energizable by the second energizing coil. If the reed or the armature is now normally biased into engagement with the lower field lamination of the first group, the reed can be attracted into conductive engagement with both of the upper laminations by the energization of the coil associated with the second group of field laminations and will be held in engagement by the continued energization of such coil or by the subsequent energization of the other coil. Thus, as will later be explained, such a relay with three field laminations, a single reed and two coils could perform all of the functions of three conventional relays equipped with an aggregate of ten contact springs.

As a further example a relay may, by the provision of twenty of such sets of field laminations and reed armatures, that is with sixty field laminations and twenty reed armatures, with two energizing coils and with the armatures intercoupled by insulating studs perform the functions of the well-known counting relay chain having twenty separate relays carrying ten transfer contact sets of three contact springs each and ten pairs of make contact springs or a total of eighty springs and the same number of soldered connections thereto as contrasted with four soldered connections in the proposed relay.

For a more comprehensive understanding of the invention reference may be had to the following detailed description taken in connection with the accompanying drawings in which:

Fig. 1 is a perspective view of a relay of the type comprehended by the present invention;

Fig. 2 is a partially exploded view of the relay of Fig. 1 more clearly disclosing certain assembly elements thereof;

Fig. 3 is a front end view of the relay of Fig. 1;

Fig. 4 is a simplified circuit diagram embodying the relay structure of Fig. 1;

Fig. 5 is a circuit diagram illustrative of the association of conventional relays all of the functions of which are accomplished by the relay structure illustrated in Figs. 1 to 3, inclusive, and installed in the circuit illustrated in Fig. 4;

Fig. 6 is a circuit diagram embodying a modification of the relay structure;

Fig. 7 is a circuit diagram illustrative of the association of conventional relays all of the functions of which are accomplished by the relay illustrated in Fig. 6;

Fig. 8 shows an armature lamination of the relay equipped with a coupling stud for use in a counting relay structure;

Fig. 9 is an end view of the lamination disclosed in Fig. 8;

Fig. 10 is a circuit diagram embodying the invention in which two reed armatures of the type disclosed in Figs. 8 and 9 are coupled together;

Fig. 11 is a circuit diagram illustrating the

association of conventional relays all of the functions of which are accomplished by the relay illustrated in Fig. 10; and

Fig. 12 is a circuit diagram illustrating the embodiment of the invention capable of counting a plurality of impulses and closing work circuits in response thereto.

Considering the fundamentals of the invention from a Boolean algebraic standpoint and in the first instance with the assumption that no coupling constraints between armature reeds of the relay are present, there are four possible positions for the field laminations associated with any one reed armature. The laminations may pass through either the right or the left energizing coil and may be positioned either above or below the armature. Furthermore, the armature reed may be arranged with its normal position either midway between the upper and lower laminations or may be allowed to rest on one or the other.

For purposes of analysis, the reed armature may be considered to be acted upon by three forces; its own stiffness, a magnetic force U tending to move the reed upwardly and a magnetic force D tending to move the reed downwardly. In compliance with the Boolean algebraic notation, I shall call U and D the hindrances in the respective magnetic circuits and express $U=0$ when there is flux tending to move the reed upwardly and $U=1$ when there is no flux and similarly $D=0$ when there is flux tending to move the reed downwardly and $D=1$ when there is no flux.

As has been previously stated a field lamination may be placed either above or below the reed armature or laminations may be placed both above and below the associated reed armature and they may pass through either the left or right coils. These possible field laminations may be designated UR if above the reed and extending through the right coil; UL if above the reed and extending through the left coil; DR if below the reed and extending through the right coil and DL if below the reed and extending through the left coil. The lamination may also be considered as coupling the coils R and L to the magnetic circuits U and D . Writing $P_{UL}=0$ if the lamination UL is present and $P_{UL}=1$ if not, with similar designations for the remaining laminations, the following Boolean expressions for the hindrances U and D may be written

$$U = (P_{UL} + L)(P_{UR} + R) \\ D = (P_{DL} + L)(P_{DR} + R)$$

where L and R are the hindrances of the left and right energizing coils. A similar pair of equations may be written for each reed armature of a given relay so that finally a set of equations

$$U' = (P_{UL}' + L)(P_{UR}' + R) \\ D' = (P_{DL}' + L)(P_{DR}' + R) \\ U^2 = (P_{UL}^2 + L)(P_{UR}^2 + R) \\ D^2 = (P_{DL}^2 + L)(P_{DR}^2 + R) \\ U^N = (P_{UL}^N + L)(P_{UR}^N + R) \\ D^N = (P_{DL}^N + L)(P_{DR}^N + R)$$

may be derived where the constants P_{UL}' , P_{UR}' , etc., are assigned values 0 or 1 which then define the mechanical arrangement of the field laminations.

The physical operation of any group of reed armatures when the magnetic variables L and R are varied is determined by the positions of the reeds when the change in L or R is made and

by the values taken on by the quantities U' , U^2 , ..., D' , D^2 , etc.

The positions of the reed will be specified by giving the hindrances $x_1, x_2, \dots, x_n$ of the front or upper contacts of two position springs. Reeds with three positions require two hindrances x and y to define their positions where x and y are the hindrances of contacts on the tops and bottoms of the reeds, respectively.

In algebraic terms then, the value of x (or x, y) is determined by X (or X, Y), the initial value of x , and by the values of U and D . Hence, for each type of construction, a table or an algebraic expression may be constructed, with X (or X, Y), U and D as independent variables and x (or x, y) as dependent variables. Consequently, if P_{UL} , etc., are assigned the values which are determined by the arrangement of the field laminations around any actual reed armature and if the equation stating U and D in terms of P_{UL} , ..., L , R are substituted in this table or algebraic expression, relations are had which define x (or x, y) in terms of X (or X, Y) and L and R , that is, the complete algebraic solution of the given reed armature is derived.

In the present analysis I have considered individual reed armatures with all possible combinations of values assigned to P_{UL} , P_{UR} , P_{DL} and P_{DR} and also all combinations of pairs of such reeds with mechanical coupling such as disclosed in Figs. 10 and 12. It will be understood, however, that any number of such reed armatures with similar or with dissimilar parameters may be combined into one relay structure as required, and also that groups of three, four or more reeds may be coupled mechanically. Many of the possible combinations are, of course, trivial in their operation. After eliminating these by inspection, some of the more important have been illustrated diagrammatically in Figs. 4, 6 and 10 as end views of the reed and field lamination combinations together with the algebraic expression of the resulting hindrances and in the associated Figs. 5, 7 and 11, the equivalent circuits composed of conventional relays have been illustrated.

Before discussing these selected illustrations, typical relay structures therefor will first be described. Reference may first be had to Figs. 1 to 3, inclusive, which disclose the relay structure diagrammatically illustrated in Fig. 4. This structure is provided with an upper left field lamination 1 and an upper right field lamination 3 positioned side by side but out of conductive engagement with each other, a single lower left field lamination 2 and a right spacing lamination 4 positioned side by side but out of conductive engagement with each other and an armature lamination 5 of the shape disclosed most clearly in Fig. 8 having a forwardly extending reed portion 6 interposed between the upper field laminations 1 and 3 and the lower field lamination 2 and spacer 4. The armature lamination 5 is insulated from the field laminations by interposed laminations 7 of insulating material. Outside of the field laminations 1 and 3, at one end of the assembly, and insulated therefrom by the lamination 8 of insulating material are positioned side by side but out of engagement with each other, a coil terminal member 9 and a spacing member 10. Outside of the coil terminal member 9 and the spacing member 10, two other coil terminal members 11 and 12 are positioned side by side but out of engagement with each other and separated from the members 9 and 10 by an interposed lamination 13 of insulating material and

outside of the members 11 and 12 and separated therefrom by a lamination 14 of insulating material is a coil supporting and clamping plate 15. Outside of the field lamination 2 and spacing member 4, at the other end of the assembly, and insulated therefrom by the lamination 16 of insulating material are positioned side by side but out of engagement with each other a coil terminal member 17 and a spacing member 18. Outside of the members 17 and 18 and insulated therefrom by the lamination 19 of insulating material are positioned side by side but out of engagement with each other two further coil terminal members 20 and 21 and, outside of the members 20 and 21 and separated therefrom by a lamination 22 of insulating material is a coil supporting and clamping plate 23.

The entire assembly is clamped together by bolts 24 which extend through aligned holes in the assembled members and which may be threaded into the holes in the lower clamping plate 23 or which may have clamping nuts upon their lower ends. The shanks of these bolts may, in the usual manner be surrounded by sleeves of insulating material such as hard rubber to insulate them from the field laminations, armature laminations and coil terminal members or the assembly structure disclosed in the Hickman-Lakatos application hereinbefore referred to may be employed thereby eliminating the insulating sleeves.

The end plates 15 and 23 are provided with out-turned ears 25 which serve as mounting brackets for the attachment of the relay structure to a suitable relay or apparatus rack and with a forwardly T-shaped portion 26, the arms of which serve as supports for the right and left operating coils R and L.

Each field lamination such as 1 is stamped from a sheet of suitable magnetic material into a U-shape most clearly disclosed in Fig. 2 and comprises one widened arm 27 which serves as a support therefor in the assembly and which is provided with two holes (not shown) through which the clamping bolts 24 extend, a narrow base portion 28 which, as later described embraces the outside of one of the operating coils and a second narrow arm 29 which serves as a pole-piece and extends through one of the operating coils. The rear end of the arm 27 is provided with a rearwardly extending terminal lug (not shown). The pole-piece arms 29 of the field laminations 1 and 2 extend through the operating coil L and the pole-piece arm 29 of the field lamination 3 extends through the operating coil R. The pole-piece arm of each field lamination has a contact 30 welded or otherwise secured to the pole face thereof facing the reed portion 6 of the armature lamination 5.

The armature lamination 5 is also stamped from a sheet of suitable magnetic material into the shape most clearly disclosed in Fig. 3 and comprises a widened base portion 31 which serves as a support therefor in the assembly and which is provided with four holes 32 through which the clamping bolts 24 extend and a tongue or reed portion 6. To give the reed portion greater length and thus greater resiliency, the base portion 31 is slotted as indicated at 33. The free end of the reed portion 6 extends freely between the inner faces of the coils L and R and between the pole-piece arms 29 of the upper field laminations 1 and 3 and the pole-piece arm 29 of the lower field lamination 2 and is provided on both faces thereof with contacts 34 welded or other-

wise secured thereto which cooperate with the contacts 30 carried by the pole-piece arms 29. The rear end of the base portion 31 is provided with a rearwardly extending terminal lug 35.

The spacing member 4 is also stamped from a sheet of suitable magnetic material of the same thickness as the field lamination into a rectangular shape and is provided with two holes through which two of the clamping bolts 24 extend. The spacing laminations 7, 8, 13, 14, 16, 19 and 22 are rectangular in shape and are stamped from a sheet of suitable insulating material such as hard rubber or fiber and each is provided with four holes through which the clamping bolts 24 extend.

The coil terminal members 9, 11, 12, 17, 20 and 21 are stamped out of sheet brass and each has a base portion serving as a support therefor in the assembly and provided with two holes through which the clamping bolts 24 extend, with a forwardly extending arm and with a rearwardly extending terminal lug. For example the terminal member 9 has an arm 36 extending forwardly and then upwardly at right angles and a terminal lug 37. The coil terminal member 17 is similar to the member 9 except that the forwardly extending arm 36 is bent downwardly. Coil terminal members 11, 12, 20 and 21 are also similar to the member 9 except that their arms 38 do not extend as far forwardly as the arm 36 of members 9 and 17 before they are bent at right angles as best disclosed in Fig. 1 and their terminal lugs 39 extend rearwardly therefrom in positions out of vertical alignment with the terminal lugs 37 of the members 9 and 17. The arms 38 of the members 11 and 12 are bent upwardly and the arms 38 of the members 20 and 21 are bent downwardly. The rectangular spacing members 10 and 18 may also be stamped from sheet brass of the same thickness as the brass from which the coil terminal members are stamped and are also each provided with two holes through which clamping bolts 24 extend.

The right coil R is provided with an outer spoolhead 40 of insulating material upon which are mounted four coil terminal lugs 41 to 44, inclusive. Each of these lugs is provided with a base member having two eyelet portions offset therefrom which extend through holes in the spoolhead 40 and are spun over on the reverse face thereof and with an arm portion which is bent around the arm portion of one of the coil terminal members. For example the arm portion 45 of the terminal lug 41 is bent around the arm portion 38 of the member 11 and is then soldered thereto. Four terminal lugs are shown secured in spoolhead 40 to connect with the terminals of the two windings of coil R. If only one winding in the coil R is necessary, two of these terminal lugs, for example, lugs 42 and 43 and the corresponding terminal members 9 and 17, the spacing members 10 and 18 and the insulating laminations 8 and 16 could be omitted from the relay assembly. The left coil L is provided with an outer spoolhead 46 to which two coil terminal lugs similar to the lugs 41 and 44 are secured for soldered connection with the arms 38 of the coil terminal members 12 and 21, respectively.

Figs. 1 to 3, inclusive, just discussed are illustrative of the manner of assembly of the different elements of the relay to secure the contact arrangement disclosed diagrammatically in Fig. 4. In this case the reed portion 6 of the armature lamination would be present before as-

sembly so that it would normally engage the contacts 34 carried on its lower face with the contacts 30 carried on the pole-piece of the lower left field lamination 3.

Considering Figs. 4 and 5, the spring combination disclosed therein may be expressed by the algebraic equation $x=LR+XL'$. If the coil L should be energized first, the reed 6 would not be operated, since the reed being normally in engagement with the pole-piece of the lower left field lamination would be held thereto by the flux generated by the coil L and flowing through the reed, through the pole-piece portion 29, base portion 28 and arm 27 of the field lamination. The subsequent energization of the coil R would then be without effect since the previous energization of the coil L would hold the reed against movement in response to the flux path set up by the coil R. If, however, the coil R should be energized first, the flux set up thereby in the upper right field lamination 3 would attract the reed 6 out of engagement with the field lamination 2 thereby opening the normally closed circuit between the terminals a and f and engage the reed 6 with the field lamination 3 thereby closing a circuit between the terminals b and f. A simple transfer is thereby effected. If thereafter the coil L is energized, the reed 6 is held thereby in engagement with the field lamination 1 and would continue to be so held following the subsequent deenergization of the coil R.

The usual relay and circuit arrangement for accomplishing this same circuit transfer and locking, as illustrated in Fig. 5, requires three relays L, R and X, the relay L having three contact springs, the relay R having two contact springs and the relay X having five contact springs or a total of three coils, ten contact springs and ten soldered connections to such springs, as contrasted with the two coils, no contact springs and the five soldered connections disclosed in the structure of Fig. 4.

In the relay structure illustrated in Fig. 6, the coil L surrounds only the pole-piece of a single field lamination 1, the lower left field lamination 2 of Figs. 1 to 3, inclusive, being replaced by a spacer member similar to member 4, the right field lamination 3 and the right spacer member 4 being interchanged so that the spacer 4 is positioned beside the field lamination 1 and the field lamination 3 is positioned beneath the reed portion 6 of the armature lamination 5. The reed 6 is normally biased into contact with the pole-piece of the field lamination 3 thereby establishing the normally closed circuit between terminals a and f. The spring combination disclosed may be expressed by the equation $x=L+XR'$. If now the coil L be first energized, the flux generated thereby in the field lamination 1 and in the reed will attract the reed out of engagement with the field lamination 3 to open the circuit between terminals a and f and into engagement with the lamination 1 to establish a circuit between terminals b and f thus effecting a simple transfer. So long as coil L remains energized, the subsequent energization of coil R is without effect. Should the coil R be first energized, then the subsequent energization of coil L would be without effect since the coil R would hold the reed 6 magnetically against the field lamination 3.

The circuit of conventional relays for accomplishing the same function is illustrated in Fig. 7 as comprising three coils L, R and X, nine contact springs and nine soldered connections to

such springs as contrasted with two coils, no contact springs and three soldered connections disclosed in the structure of Fig. 6.

Fig. 10 illustrates a further relay assembly comprising a unit of three field laminations 1, 2 and 3 and an armature reed 6 arranged in the manner disclosed in Figs. 1 to 4, inclusive, and a second similar unit comprising three field laminations 1', 2' and 3' arranged reversely to the similar laminations of the other unit and an armature reed 6'. The left coil L surrounds the pole-pieces of the three field laminations 1, 2 and 3' and the right coil R surrounds the pole-pieces of the field laminations 1', 2' and 3. The reed 6 is also provided near its forward end with a stud 47 of insulating material, ring-staked thereto and having its free end normally engaged against the upper face of the reed 6'. Normally the reeds 6 and 6' are both biased to engage with the pole-pieces of field laminations 2 and 2', respectively. The spring combination disclosed therein may be expressed by the algebraic equations

$$\begin{aligned}x_1 &= LR + L'X_1 \\x_2 &= LR + X_1 + R'X_2\end{aligned}$$

If coil L is first energized, no motion of the reed armatures 6 and 6' is produced because the flux generated by the coil L in the field lamination 2 will hold the reed 6 in engagement with the pole-piece thereof and the flux generated in the field lamination 3' will not be able to attract the reed 6' to its pole-piece because the reed will be prevented from moving by the stud 47. If the coil R is now energized neither reed 6 nor 6' will be able to move since reed 6 is held magnetically against the field lamination 2 by the prior energization of coil L and the reed 6' will be held magnetically against the field lamination 2' by the energization of coil R.

If coil R is first energized, reed 6 will be attracted into engagement with the field lamination 3 thereby moving the stud from the reed 6' but the reed 6' will not be attracted to the field lamination 1' since it is held magnetically against the field lamination 2' by the flux generated therein by the coil R. If now, coil L is energized, the operated reed 6 becomes magnetically locked to the field lamination 1, but the flux set up in the field lamination 3' will be unable to move reed 6' since it is held magnetically against the lamination 2' by the continued energization of coil R. If coil R now becomes deenergized, reed 6 is held in engagement with the lamination 1 by the energized coil L and since reed 6' is now no longer held magnetically against the lamination 2' it is now attracted into engagement with the lamination 3'.

In the analogous group of conventional relays shown in Fig. 11, relays L and R correspond to the coils L and R of Fig. 10 and relays X₁ and X₂ correspond to the reeds 6 and 6' respectively. If relay R is first operated, with relay L unoperated, it causes the operation of relay X₁ which locks over its upper contacts and the front contacts of relay R independently of relay L. When thereafter relay L operates, it closes a new locking circuit for relay X₁ and prepares an operating circuit for relay X₂ which is established upon the subsequent release of relay R over the front contacts of relay L, the back contact of relay R and the inner contacts of relay X₁. Relay X₂ upon operating locks over its own contacts and the front contacts of relay L and remains operated until relay L releases. Thus this

circuit requires four relay coils, twelve contact springs and twelve soldered connections thereto whereas the relay structure of Fig. 10 which performs the same functions requires but two coils, no contact springs and no soldered connections.

Fig. 12 illustrates the relay structure of Fig. 10 further expanded for the purpose of counting impulses. The relay structure illustrated is capable of counting three impulses. The right coil R is divided into two equal windings R' and R² wound differentially with respect to each other. To prepare the circuit for counting impulses, the keys 48 and 50 are operated, key 48 closing an obvious circuit for operating relay 80 and key 50 closing a circuit extending from the negative terminal of battery over the contacts of key 50, through windings R', R² and L in series to the other terminal of the battery 49. With relay 80 operated, the left winding L becomes energized to cause a flow of flux in the pole-pieces of all of the field laminations associated therewith, but due to the differential arrangement of the windings R' and R², no flow of flux is generated in the pole-pieces of the field laminations associated therewith.

With the winding L energized all of the even-numbered reed armatures 72, 74, 76 and 78 are held magnetically against the lower field laminations 52, 55, 58 and 61, linked with the winding L and through the studs 47 carried thereby hold the odd-numbered reed armatures 73, 75 and 77 against the lower field laminations 64, 67 and 70, linked with the right windings R' and R² so that they cannot be attracted to the upper field laminations 53, 56 and 59 linked with the energized winding L. When the dial 79 is rotated by the insertion of a finger in the No. 3 finger-hole thereof until the finger engages the usual finger-stop, and the dial is then released, the circuit of relay 80 is opened and then closed three times during the return of the dial to normal.

Upon the first release of relay 80, the left winding L and the winding R² become short-circuited over the contacts of relay 80 and the winding R' becomes effectively energized in a circuit from battery 49 over the contacts of key 50 and over the contacts of relay 80. With winding R' now effective, reed 72 is attracted upwardly into engagement with the field lamination 62 thereby moving its stud 47 out of engagement with the next reed 73, but this reed is now held magnetically against the lower field lamination 64 linked with the coil R' and through its stud 47 prevents the next reed 74 from being attracted upwardly toward the magnetized field lamination 55. Reed 75 is also held magnetically against the lower field lamination 67 linked with the coil R' and through its stud 47 prevents the next reed 76 from being attracted upwardly toward the magnetized field lamination 68. Similarly reed 77 is held magnetically against the lower field lamination 70 linked with the coil R' and through its stud 47 prevents the next reed 78 from being attracted upwardly toward the magnetized field lamination 71. Thus with the winding L deenergized and the winding R' effectively energized only the upper reed 72 is moved, the odd-numbered reeds 73, 75 and 77 being held down magnetically and the even-numbered reeds 74, 76 and 78 being held down by the engagement of the studs of the odd-numbered reeds therewith.

On the next energization of relay 80 upon the termination of the first impulse transmitted by the dial 79, the shunt around the left winding L and the right winding R² is opened and the two

windings R' and R² again become connected differentially in the circuit of winding L. Winding L now becomes energized and the windings R' and R² become ineffective, but the winding L energizes before current builds up sufficiently in the winding R² to oppose the current flowing through the winding R' to render winding R' ineffective so that the operated reed 72 is held locked to the upper magnetized field lamination 51 linked with the winding L. Since the stud 47 of reed 72 is now out of engagement with reed 73 and reed 73 is no longer held magnetically against the field lamination 64, it is now attracted upwardly into engagement with field lamination 53 which is linked with the energized winding L. A circuit is now established from ground over field lamination 53, reed 73 connected with reed 74 by conductor 81, field lamination 55 against which reed 74 is held magnetically by the winding L and thence to battery through the lamp 82. The lighting of lamp 82 indicates the counting of one received impulse. Reeds 76 and 78 are also held magnetically against the field laminations 58 and 61, respectively, which are linked with the energized winding L and reeds 74 and 76 through their studs 47 hold reeds 75 and 77 against attraction toward the magnetized field laminations 56 and 59.

Upon the deenergization of relay 80 in response to the next impulse from the dial 79, the shunt of windings L and R² is reestablished and the winding R' again becomes effective. Following the deenergization of winding L, the operated reeds 72 and 73 are held in their operated positions by the magnetization of field laminations 62 and 63 linked with the winding R'. Since the left winding L is now deenergized, the reed 74 is no longer held magnetically against the field lamination 55 and since the reed 73 has been operated and moved its stud 47 from engagement with reed 74, this reed now becomes attracted into engagement with the field lamination 65 linked with the winding R', and upon leaving the field lamination 55 opens the circuit of lamp 82. Reeds 75 and 77 are now held magnetically against the field laminations 67 and 70 linked with the winding R' and through their associated studs 47 hold the reeds 76 and 78 against attraction towards the field laminations 68 and 71 linked with the winding R'.

Upon the next energization of relay 80, upon the termination of the second impulse transmitted by the dial 79, the shunt around the left winding L and the right winding R² is opened and the two windings R' and R² again become connected differentially in the circuit of winding L whereupon winding L energizes and the right windings R' and R² become ineffective. The three operated reeds 72, 73 and 74 are now held locked magnetically to the field laminations 51, 53 and 54, respectively, linked with the energized winding L. Since the stud 47 of reed 74 is now out of engagement with reed 75 and reed 75 is no longer held magnetically against the field lamination 67, it is now attracted upwardly into engagement with field lamination 56 linked with the energized winding L. A circuit is now established from ground over field lamination 56, reed 75 connected with reed 76 by conductor 83, field lamination 58 against which reed 76 is held magnetically by the energized winding L and thence to battery through the lamp 84. The lighting of lamp 84 indicates the counting of two received impulses. Reed 78 is also held magnetically against the field lamination 61 linked with the energized

winding L and reed 77 is held by stud 47 of reed 76 against attraction toward the magnetized lamination 59.

Upon the next deenergization of relay 80, in response to the next impulse from the dial 79, the shunt of windings L and R² is reestablished and the winding R' again becomes effective. Following the deenergization of winding L, the operated reeds 72 to 75, inclusive, are held in their operated positions by the magnetization of the field laminations 62, 63, 65 and 66 linked with the winding R'. Since the left winding L is now deenergized, the reed 76 is no longer held magnetically against the field lamination 58 and becomes attracted into engagement with the field lamination 68 linked with winding R' and upon leaving the field lamination 58 opens the circuit of lamp 84. Reed 77 is now held magnetically against the field lamination 70 linked with winding R' and, through its stud 47, holds reed 78 against attraction toward the field lamination 71 linked with winding R'.

On the next energization of relay 80, upon the termination of the third impulse transmitted by the dial 79, the shunt around the left winding L and the right winding R² is opened and the two windings R' and R² again become connected differentially in the circuit of winding L whereupon winding L energizes and the right winding R' and R² become ineffective. The operated reeds 72 to 76, inclusive, are now held locked magnetically to the field laminations 51, 53, 54, 56 and 57, respectively, linked with the energized winding L. Since the stud 47 of reed 76 is now out of engagement with reed 77 and reed 77 is no longer held magnetically against the field lamination 70, it is now attracted upwardly into engagement with the field lamination 59 linked with the energized winding L. A circuit is now established from ground over field lamination 59, reed 77 connected with reed 78 by conductor 85, field lamination 61 against which reed 78 is held magnetically by the energized winding L and thence to battery through the lamp 86. The lighting of lamp 86 indicates the counting of three received impulses. To restore the operated reeds of the relay structure to their normal positions, the keys 48 and 50 are released.

It will be obvious that any desired number of impulses could be counted in a similar manner by the addition of two reeds and six associated field laminations for each additional impulse to be counted. Thus a relay structure capable of counting ten impulses would require twenty reeds and sixty field laminations.

While the foregoing illustrations have been selected to demonstrate the invention, it is to be understood that other combinations of field laminations and reeds could be arranged to effect any desired contact combination and that the scope of the invention is to be determined only by the appended claims.

What is claimed is:

1. In a relay, a first and a second field lamination of magnetic material positioned in parallel layers, a first energizing coil surrounding said laminations, a third field lamination of magnetic material positioned in the layer of said first lamination and out of conductive engagement therewith, a second energizing coil surrounding said latter lamination, a reed of magnetic material attractable into engagement with any one of said laminations, and laminations of insulating material interposed between said laminations and said reed, said reed being normally

biased into engagement with said second lamination whereby it may be moved out of engagement therewith and into engagement with said other laminations only by the initial energization of said second coil and may be held in its attracted position by the continued energization of said second coil or the subsequent energization of said first coil.

2. In a relay, two groups of field laminations of magnetic material, reeds of magnetic material attractable into conductive engagement with laminations of both groups, laminations of insulating material interposed between said laminations and between said laminations and said reeds, energizing coils surrounding said groups of laminations, respectively, and mechanical coupling means extending between adjacent reeds whereby upon the sequential energization and deenergization of said coils, said reeds are operated sequentially.

3. In a relay, two groups of field laminations of magnetic material, reeds of magnetic material attractable into conductive engagement with laminations of both groups, laminations of insulating material interposed between said laminations and between said laminations and said reeds, energizing coils surrounding said groups of laminations respectively, a plurality of work circuits and mechanical coupling means extending between adjacent reeds whereby upon the sequential energization and deenergization of said coils said reeds are operated sequentially to successively establish said work circuits.

4. In a relay, two groups of filed laminations of magnetic material, reeds of magnetic material attractable into conductive engagement with laminations of both groups, laminations of insulating material interposed between said laminations and between said laminations and said reeds, energizing coils surrounding said groups of laminations, respectively, a plurality of work circuits and studs of insulating material secured to certain of said reeds and having their ends engaged against adjacent reeds, whereby upon the sequential energization and deenergization of said coils, said reeds are operated sequentially to successively establish said work circuits.

5. In a relay, two groups of field laminations of magnetic material, reeds of magnetic material attractable into conductive engagement with laminations of both groups, laminations of insulating material interposed between said laminations and between said laminations and said reeds, energizing coils surrounding said groups of laminations, respectively, one of said coils comprising two differentially wound windings, studs of insulating material secured to certain of said reeds and having their ends engaged against adjacent reeds, and means for sequentially connecting one of said coils and the two windings of said other coil differentially in series and then establishing a shunt around one of said coils and one winding of said other coil whereby said reeds are operated sequentially.

6. In a relay, a first set of field laminations of magnetic material, the first and second laminations of which are positioned in parallel layers and the third lamination of which is positioned in the layer of the first lamination and out of conductive engagement therewith, a second set of field laminations having its laminations arranged reversely to those of said first set to form two groups of laminations, one comprising the first and second laminations of the first set and the third lamination of the second set and the

other comprising the first and second laminations of the second set and the third lamination of the first set, a reed of magnetic material associated with each set of laminations normally biased into engagement with the second lamination thereof and attractable into engagement with any lamination of the set, laminations of insulating material interposed between adjacent laminations and between adjacent laminations and reeds, energizing coils surrounding said groups of laminations respectively, and a stud of insulating material secured to the reed of said first set and engaged against the reed of said second set, whereby upon the sequential energization of said coils in a definite order and the release of the first operated coil, said reeds are operated sequentially.

7. In a relay, a first set of field laminations of magnetic material, the first and second laminations of which are positioned in parallel layers and the third lamination of which is positioned in the layer of the first and out of conductive engagement therewith, a second set of field laminations having its laminations arranged reversely to those of said first set to form two groups of laminations, one comprising the first and second laminations of the first set and the third lamination of the second set, and the other comprising the first and second laminations of the second set and the third lamination of the first set, a reed of magnetic material associated with each set of laminations normally biased into engagement with the second lamination thereof and attractable into engagement with any lamination of its set, laminations of insulating material interposed between adjacent laminations and between adjacent laminations and reeds, energizing coils surrounding said groups of laminations, respectively, and a stud of insulating material secured to the reed of said first set and engaged against the reed of said second set, whereby upon the energization of one of said coils, the reed of the first set is moved into engagement with the third lamination thereof and the reed of the second set is magnetically held against the second lamination of its set, whereby upon the subsequent energization of said other coil the reed of the first set is held magnetically against the first lamination thereof and whereby upon the subsequent release of said one coil the reed of the second set is attracted into engagement with the third lamination of its set by the continued energization of said other coil, thus operating said reeds sequentially.

8. In a relay, a plurality of sets of field laminations of magnetic material, the first and second laminations of each set being positioned in parallel layers and the third lamination of each set being positioned in the layer of said first lamination and out of conductive engagement therewith, adjacent sets of said laminations being assembled reversely to form two groups of laminations, one comprising the first and second laminations of the odd-numbered sets and the third laminations of the even-numbered sets, and the other group comprising the first and second laminations of the even-numbered sets and the third laminations of the odd-numbered sets, a reed of magnetic material associated with each set of laminations and attractable into engagement therewith, laminations of insulating material interposed between adjacent laminations and between adjacent laminations and reeds, energizing coils surrounding said groups of laminations, respectively, and studs of insulating materials se-

cured to certain of said reeds and having their ends engaged against adjacent reeds, whereby upon the sequential energization and deenergization of said coils, said reeds are operated sequentially.

9. In a relay, a first plurality of sets of field laminations each comprising three laminations of magnetic material, the first and second of which are positioned in parallel layers and the third of which is positioned in the layer of the first and out of conductive engagement therewith, a second plurality of sets of field laminations alternated with the sets of said first plurality and each having its laminations arranged reversely to the laminations of said first sets to form two groups of laminations, one comprising the first and second laminations of the sets of said first plurality and the third laminations of the sets of said second plurality and the other comprising the first and second laminations of the sets of said second plurality and the third laminations of the sets of said first plurality, a reed of magnetic material associated with each set of laminations and normally biased into engagement with the second lamination thereof and attractable into engagement with any lamination of its set, laminations of insulating material interposed between adjacent laminations and between adjacent laminations and reeds, energizing coils surrounding said groups of laminations, respectively, and studs of insulating material secured to certain of said reeds and having their ends engaged against the adjacent reeds, whereby upon the energization of one of said coils, the reed of the first set of said first plurality of sets is moved into engagement with the first and third laminations thereof, the reeds of the second plurality of sets are held magnetically against the third lamination of their sets and the reeds of the remaining sets of the first plurality are held mechanically by the studs of the other reeds, whereby upon the subsequent energization of said other coil, the operated reed is held magnetically against the first lamination of its set and the remaining reeds of the first plurality of sets are held magnetically against the third laminations of their sets and through their studs hold the remaining reeds of the second plurality of sets against the third laminations thereof, and whereby upon the subsequent release of said one coil, the reed of the first set of the second plurality is attracted into engagement with the third lamination of its set, the unoperated reeds of the first plurality of sets are held magnetically against the third laminations thereof, and the unoperated reeds of the second plurality of sets are held against the third laminations of their sets by the continued energization of said other coil, said sequence of operations being completed by the reenergization of said one coil followed by the release of said other coil and repeated sequences of operations causing the sequential operation of the remaining reeds.

10. In a relay, a first and a second pole-piece positioned in parallel planes, a first energizing coil surrounding said pole-pieces, a third pole-piece positioned in the plane of the first pole-piece and out of conductive engagement therewith, a second energizing coil surrounding said latter pole-piece and an armature attractable into engagement with any one of said pole-pieces, said armature being normally biased into engagement with said second pole-piece whereby it may be moved out of engagement therewith and into engagement with said other pole-pieces only by the initial energization of said second coil and may be held in

its attracted position by the continued energization of said second coil or by the subsequent energization of said first coil.

11. In a relay, two groups of pole-pieces, armatures attractable into engagement with pole-pieces of both groups, energizing coils surrounding said groups of pole-pieces respectively, and mechanical coupling means extending between adjacent armatures whereby upon the sequential energization and deenergization of said coils said armatures are operated sequentially.

12. In a relay, a plurality of sets of pole-pieces, the first and second of each set being positioned in parallel planes and the third of each set being positioned in the plane of the first pole-piece, adjacent sets of said pole-pieces being assembled

reversely to form two groups of pole-pieces, one comprising the first and second pole-pieces of the odd numbered sets and the third pole-pieces of the even numbered sets, and the other group comprising the first and second pole-pieces of the even numbered sets and the third pole-pieces of the odd numbered sets, an armature associated with each set of pole-pieces and attractable into engagement therewith, energizing coils surrounding said groups of pole-pieces, respectively, and studs of insulating material secured to certain of said armatures and having their ends engaged against adjacent armatures, whereby upon the sequential energization and deenergization of said coils said armatures are operated sequentially.

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