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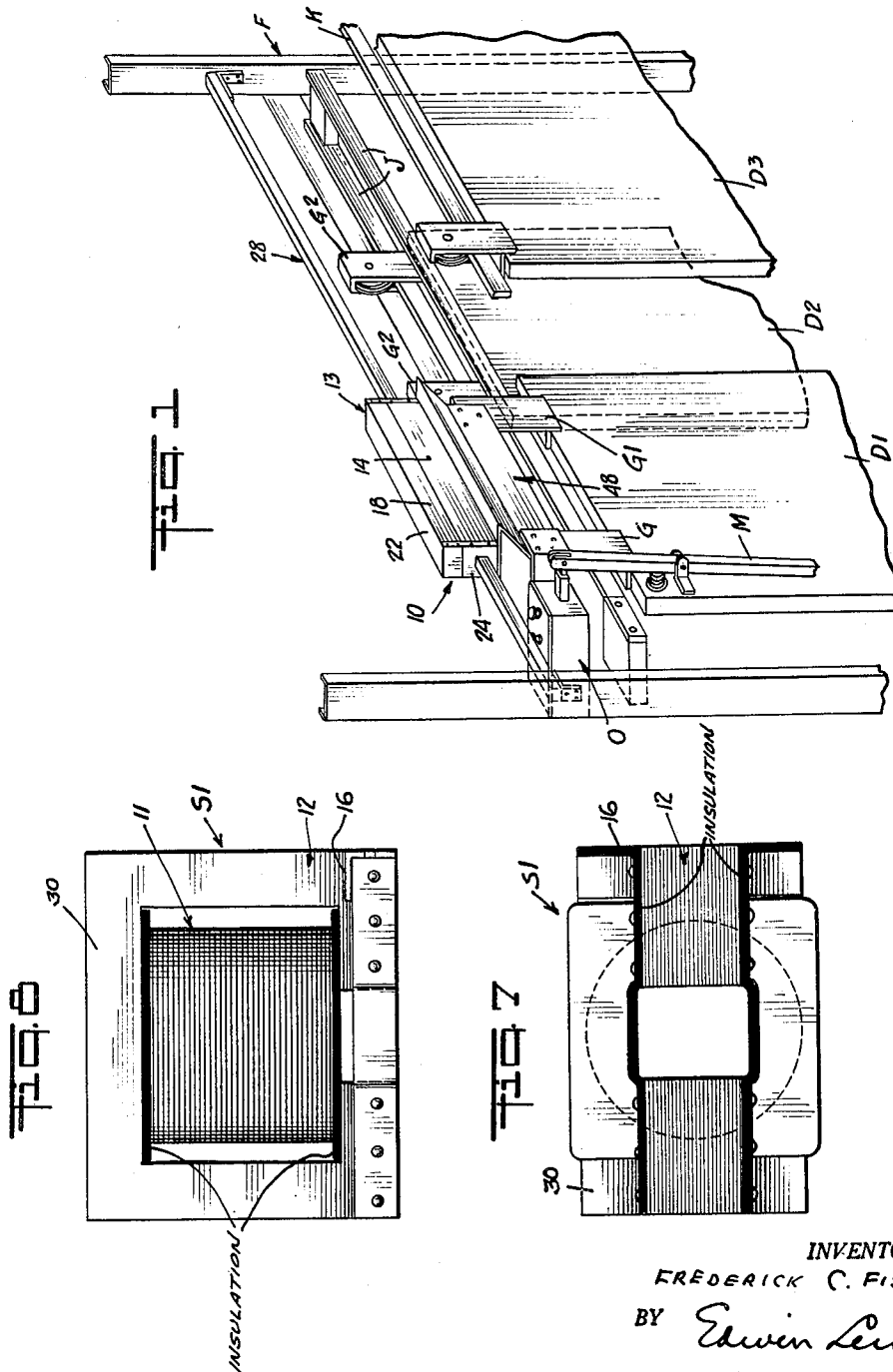
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ELECTROMAGNETIC MOTIVE MEANS

Filed Oct. 1, 1942

7 Sheets-Sheet 1



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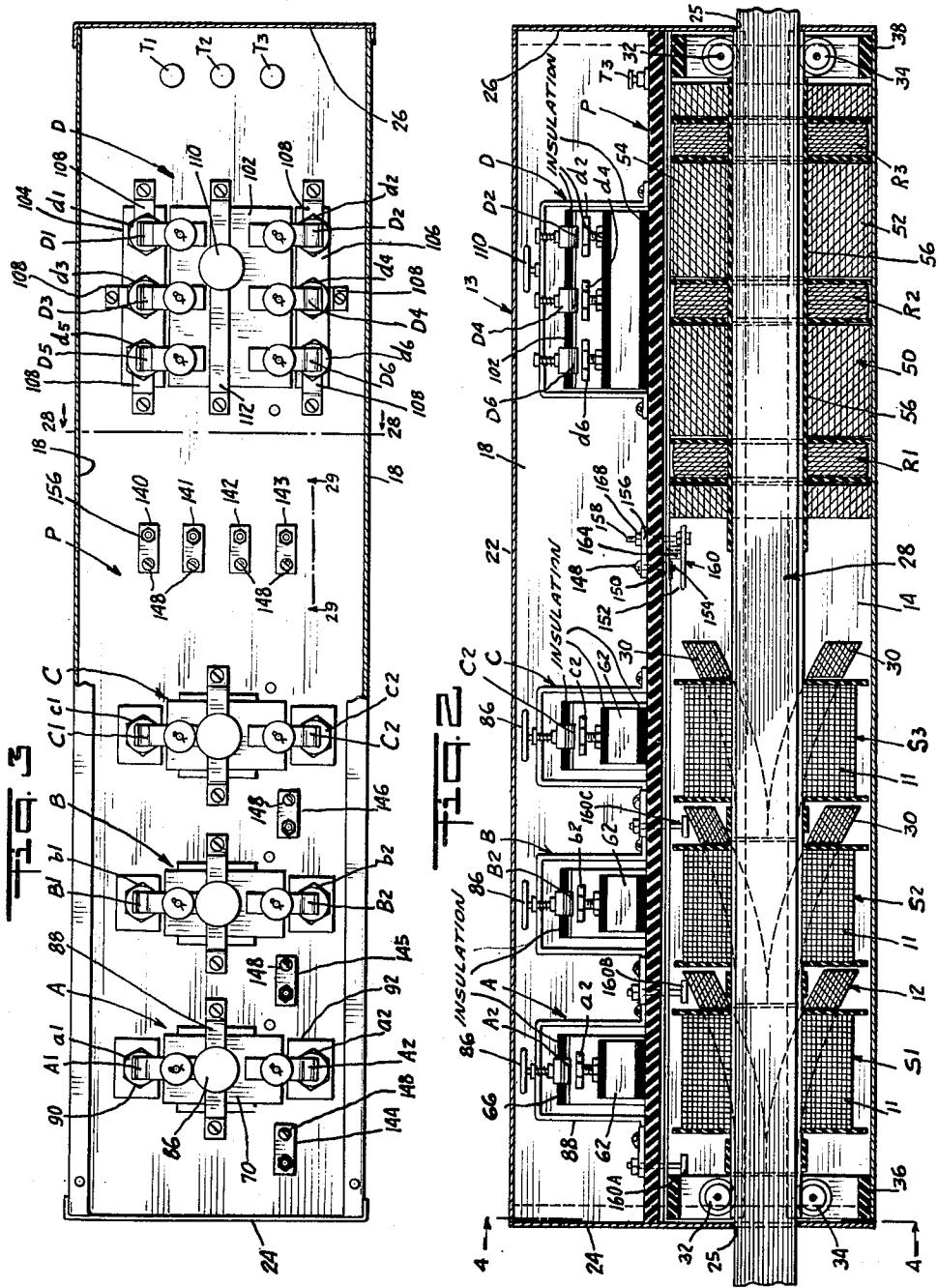
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ELECTROMAGNETIC MOTIVE MEANS

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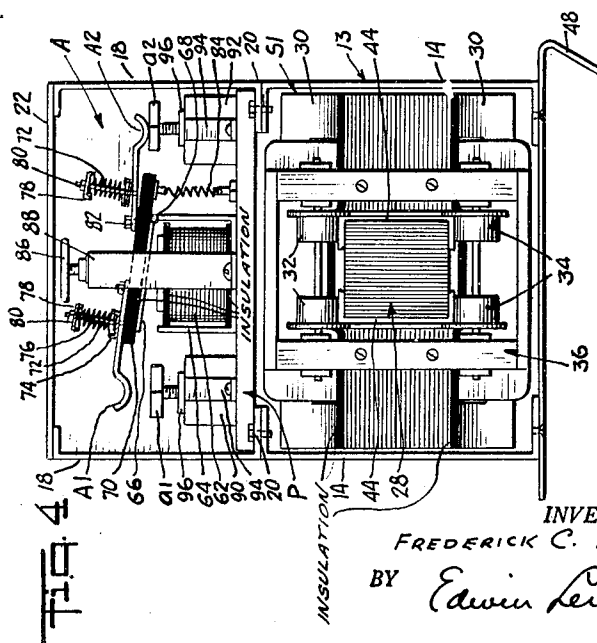
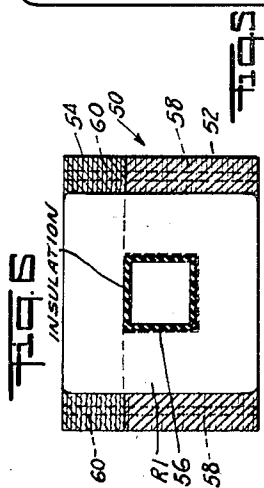
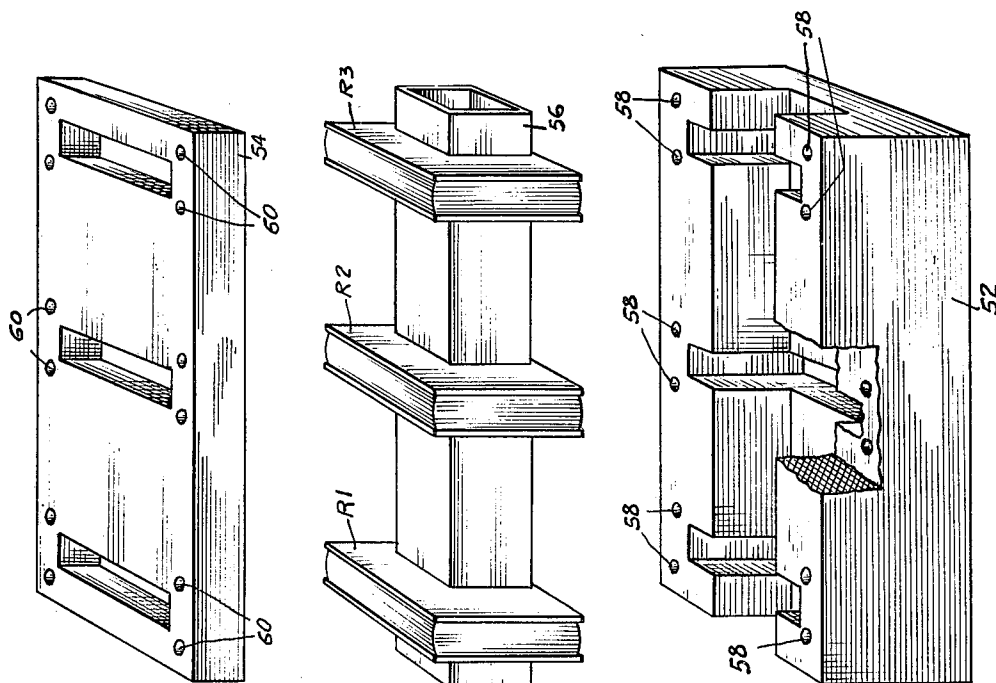
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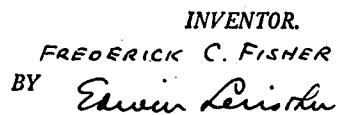
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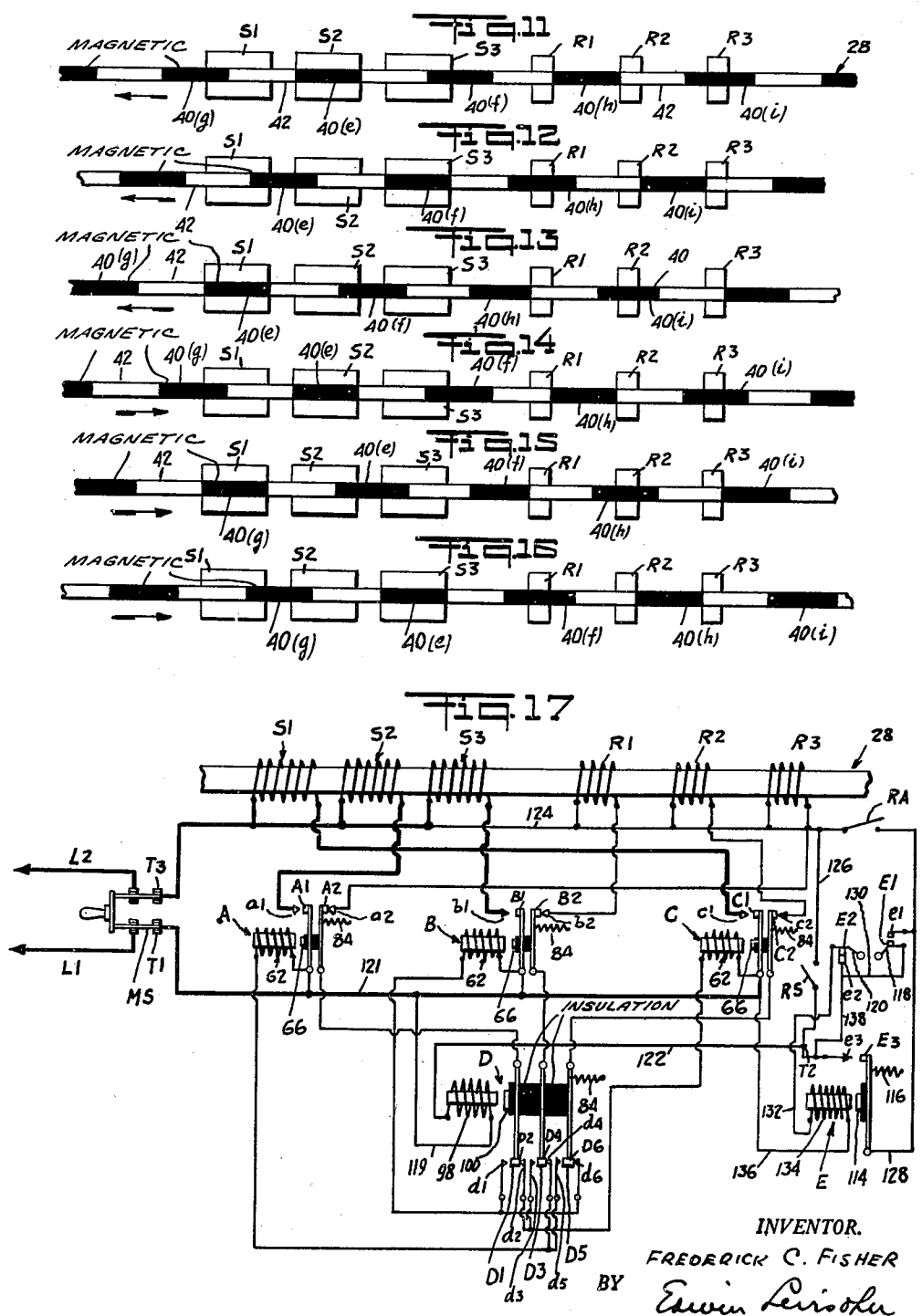
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ELECTROMAGNETIC MOTIVE MEANS

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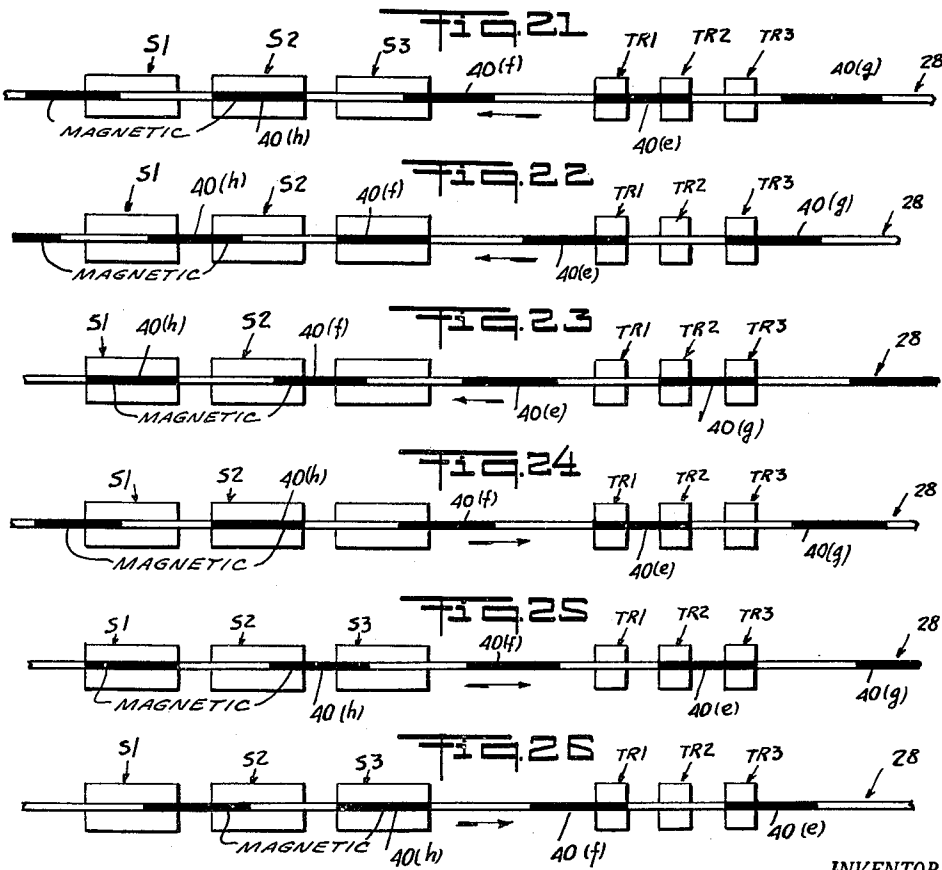
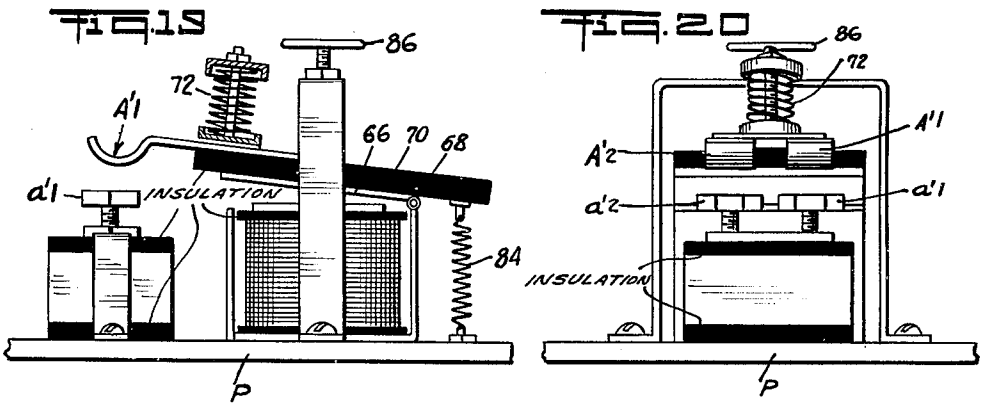
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ELECTROMAGNETIC MOTIVE MEANS

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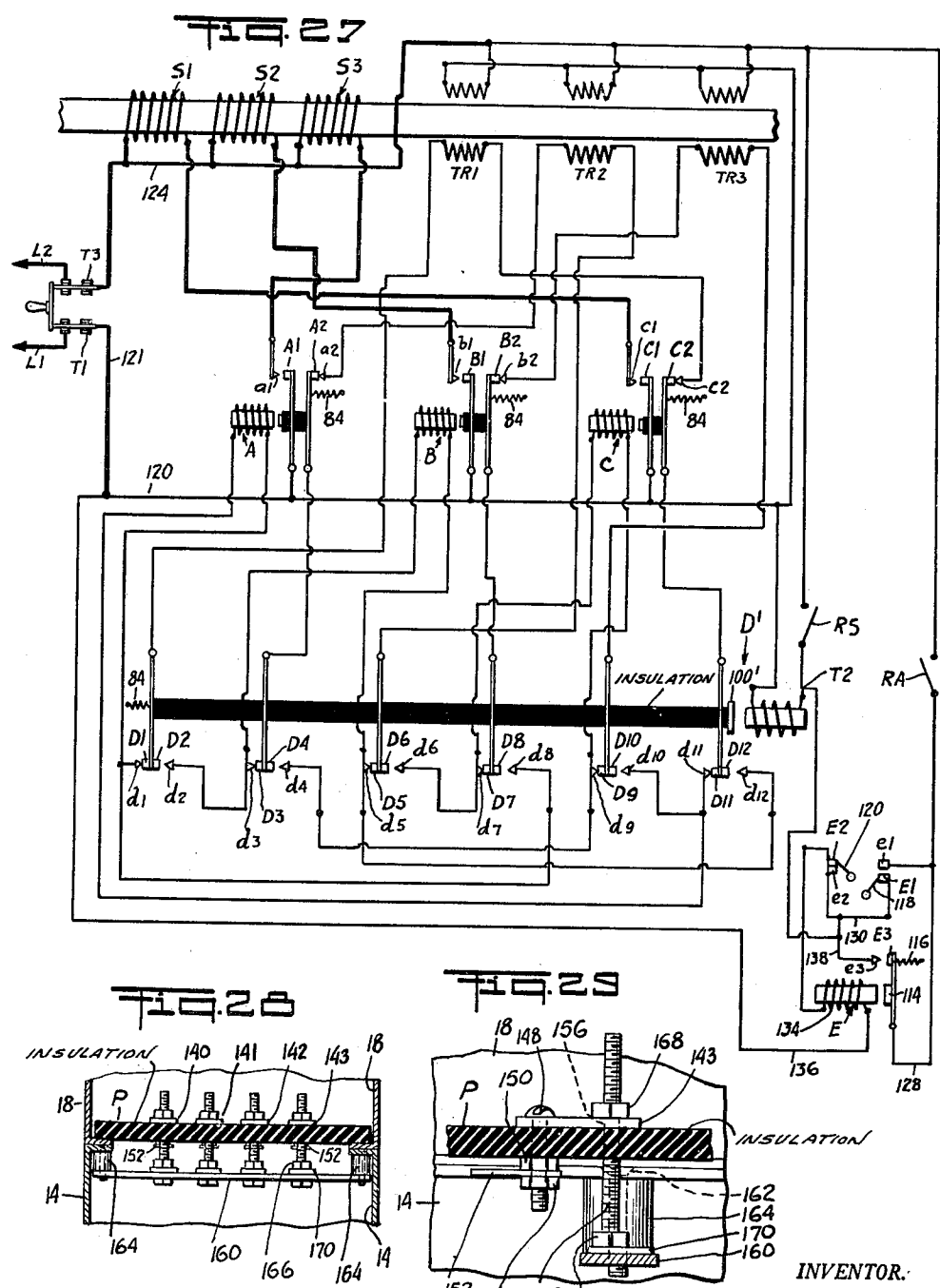
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ELECTROMAGNETIC MOTIVE MEANS

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7 Sheets-Sheet 7



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UNITED STATES PATENT OFFICE

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ELECTROMAGNETIC MOTIVE MEANS

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Application October 1, 1942, Serial No. 460,398

21 Claims. (Cl. 172—290)

This invention relates to electro-magnetic motive means which, while useful for other purposes, is intended primarily for operating the doors of elevators. This application is a continuation in part of my application, Ser. No. 300,018, filed October 18, 1939, now Patent No. 2,303,263, Nov. 24, 1942.

The electro-magnetic motive means of the present invention is, in general, of the type disclosed in my said application Ser. No. 300,018 and in accordance with the present invention and pursuant to one of the objects thereof, the solenoid windings are energized in the proper sequence by means controlled by the relative movement between the solenoids and the solenoid plunger and operable in such manner as to eliminate the use of switch operating mechanisms. More specifically, in accordance with the present invention the solenoids are connected to and disconnected from the line at the proper times by electrically operated relays, the operation of which are electrically controlled by current varying means whereby to produce a relative movement of the solenoids and their plunger, the movement of the solenoids or their plunger as the case may be being smooth and continuous and of the length of travel necessary for actuating the device operated thereby.

Also, in accordance with the present embodiment of the invention, the continuous relative movement of the solenoids and plunger is obtained by spacing the solenoids, longitudinally of the solenoid plunger, one-third of the axial length of a solenoid winding, the axial lengths of the solenoid windings being equal and the magnetic and non-magnetic sections of the plunger being each equal to the axial length of the solenoid winding. This enables the solenoids to be spaced more closely than in the apparatus disclosed in my above mentioned application while at the same time obtaining the smooth and continuous relative movement of the solenoid windings and the plunger. This constitutes another object of the present invention.

A further object of the invention is to provide an electro-magnetically operated device which operates under the control of current varying means which is responsive to the action of an iron core or plunger. In accordance with this object of the invention and pursuant to one form thereof, the current varying means is a reactance device including a reactance coil, the inductance reactance of which is increased when said core is entered into said winding; and pursuant to

another form of the invention, the current varying means is a transformer in which the secondary current is increased when the iron core is entered into the transformer winding.

5 In accordance with a more specific object of the invention, the iron core which forms a part of the current varying means is operated by one or more solenoids, preferably but not necessarily as part of the solenoid plunger, and the electro-magnetically controlled means which operates under the control of the current varying means controls, in turn, the operation of the solenoid or solenoids.

Another object of the invention is, more generally, to control the relative movement between the relatively movable parts of an electro-dynamic device by current varying means such as reactance means or electric transformers.

The above and other objects, features and advantages of this invention will be fully understood from the following description, considered in connection with the accompanying illustrative drawings.

In the drawings:

25 Fig. 1 is a perspective view of the electro-magnetic motive means of the present invention operatively connected to the door of an elevator cab for operating the same;

30 Fig. 2 is a side view in elevation, with parts in section, of the motive device;

Fig. 3 is a top plan view of the device, the top of the casing being removed, and parts of the top of the casing being cut away for the purpose of illustration;

35 Fig. 4 is an end view of the device, seen along the line 4—4 of Fig. 2, when the end closure of the casing is removed;

Fig. 5 is an exploded perspective view of the parts of the reactance structure;

40 Fig. 6 is a transverse sectional view of the reactance structure;

Figs. 7 and 8 are end and top views, respectively, of the solenoid;

45 Fig. 9 is a side view of the plunger, parts being broken away for the purpose of illustration;

Fig. 10 is a sectional view of the plunger on the line 10—10 of Fig. 9;

50 Figs. 11 to 16, inclusive, are diagrammatic views illustrating the operation of the motive device of the present invention;

Fig. 17 is a more or less diagrammatic view of the motive device and of the electric circuit;

Fig. 18 is a circuit diagram similar to Fig. 17, 55 illustrating a modification;

Fig. 19 is a side view of a control relay of the type utilized in the circuit shown in Fig. 18;

Fig. 20 is a front view of the relay shown in Fig. 19;

Figs. 21 to 26, inclusive, are diagrammatic views similar to Figs. 11 to 16, inclusive, illustrating another form of the invention;

Fig. 27 is a circuit diagram of the form of the invention illustrated in Figs. 21 to 26;

Fig. 28 is a transverse sectional view, on a larger scale, on the line 28—28 of Fig. 3;

Fig. 29 is a sectional view on the line 29—29 of Fig. 3.

Referring now to the drawings in detail, the electro-magnetic motive device 10 embodying the present invention is shown operatively connected to an elevator door D1 of an elevator car for opening and closing the latter, but it will be understood that said motive device can be utilized for other purposes. Part of the frame of the elevator car is indicated at F and said door D1 and the other door D2 of the elevator car, said doors being coupled together for movement in the usual way longitudinally of the fixed tracks J, are suspended at their upper ends by means of wheel bracket G1 and G2. In Fig. 1 is also shown a corridor door D3 suspended from and movable longitudinally of the track K fixed to the corridor wall. The corridor door D3 is shown displaced from its normal position in relation to the elevator car door D1 for the sake of clearness of illustration, and it will be understood that doors D1 and D3 are normally in side by side relation to permit them to be coupled and uncoupled in a suitable way, for example, in the manner illustrated in my above mentioned application. Parts of an electrically operated device for coupling and uncoupling doors D1 and D3 are indicated at O and M in Fig. 1, and require no further description as they do not form part of the present invention.

The elevator car door D1 is opened and closed directly by an electro-magnetic device 10 of the present invention. Said device comprises three solenoids S1, S2 and S3, all of the same construction, and each having a winding or coil 11 and a laminated iron core 12, being as here shown designed for alternating current operation. Said solenoids are secured in a frame 13 comprising opposed channel irons 14 as shown in Figs. 2 and 4, one of said channel irons being omitted from Fig. 2 in order to disclose the solenoids. The cores 12 have brackets 16 secured thereto by which they are fixed to the channel irons 14. The frame 13 which comprises the channel irons 14 also include opposed channel irons 18 secured to the upper flanges of the adjacent channel irons 14 in any suitable way as by bolts 20. A cover plate 22 is provided for the top of the housing and removable end closure members 24 and 26 are provided at the opposite ends of frame 13, said end closure members having an opening 25 for the passage of the solenoid plunger 28. Channel irons 18 constitute a housing for the relays A, B, C and D which will be subsequently described.

The solenoid plunger 28 is mounted in fixed position at the top of the elevator car, as illustrated more or less diagrammatically in Fig. 1, and extends through the three solenoids, as shown in Fig. 2, the latter being movable longitudinally of said plunger. In order to permit plunger 28 thus to extend through the solenoids, the cores 12 of the latter are split as illustrated in Fig. 2, and shown in my prior application,

forming divided core portions 30 between which plunger 28 projects. It will be understood that the three solenoids are mounted in alignment so that said solenoids can move longitudinally of the plunger. Housing 13 is supported for movement longitudinally of plunger 14 by upper and lower pairs of rollers 32 and 34, respectively, carried by bearing frames 36 and 38 fixed at the opposite ends of channel irons 14 in any suitable way. Plunger 28 is thus prevented from sagging and a proper slight clearance between the solenoid windings and the plunger is thus provided.

Plunger 28 comprises magnetic sections 40 and non-magnetic sections 42 (Fig. 9) arranged alternately adjacent each other in abutting end to end relation and secured in said relation by a pair of longitudinally extending channel members 44 of brass or other non-magnetic material. Magnetic sections 40 are laminated being composed of sheet iron or laminae, and non-magnetic sections 42 are composed of fibre board, wood or other suitable non-magnetic material. Members 44 are spaced from each other to prevent or reduce eddy current losses. The end sections 40 of the plunger are securely fastened to members 44 in any suitable way as by bolts 46, the ends of which are flush with the outer surfaces of members 44. Plunger 28 is thus constituted by a solid square rod composed of magnetic and non-magnetic sections in a split brass or other non-magnetic casing. The magnetic and non-magnetic sections 40 and 42 of the plunger are of the same length and each magnetic and non-magnetic section is equal to the axial length of the solenoid winding. The three solenoids are of the same length and they are in spaced relation in the direction of the longitudinal extent of plunger 28, the spacing being equal to one-third of the axial length of a solenoid winding. It will be understood that the length of the solenoid winding will depend on the space available and the power required. When direct current is used, magnetic sections 40 need not be laminated and the casing of the plunger need not be split and it will be understood also that with direct current plunger 28 can have a circular cross section and the solenoid coils can be cylindrical.

With the above described arrangement of the plunger and the three solenoids, it will be found that when one of the magnetic sections of the plunger is just entering one of the solenoid windings in either direction, another magnetic section will be almost completely entered in the winding of a second solenoid, while another magnetic section will be leaving the winding of a third solenoid. Accordingly, by energizing the solenoid windings in such a manner that only the winding in which the magnetic section of the plunger is beginning to enter is energized and automatically de-energized when said magnetic section is fully entered, and at the same time relaying the power to the next solenoid winding, a continuous thrusting movement of the frame 13 to which said solenoids are secured will result. This movement is transmitted to the elevator car D1 or to some other device, as the case may be, by connecting the solenoid carrying frame 13 to the elevator door. By way of illustration, this is accomplished, as here shown, by means of a bracket 48 secured to the bottom flanges of channel irons 14 and to brackets G1 of door D1.

The means for controlling the energizing and

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deenergizing of the solenoid sequence whereby to obtain the above mentioned smooth and continuous thrusting movement will now be described. Said means comprises the current varying means, which in one form of the invention includes the reactance structure 50 mounted in stationary position between channel irons 14 in frame 13. Said reactance structure comprises three identical reactance or choke coils R1, R2 and R3 positioned in longitudinally spaced relation within a laminated iron shell formed of the parts 52 and 54 (Figs. 2, 5 and 6). Said reactance coils are mounted on and fixed to a hollow non-magnetic tube 56 through which plunger 28 is movable with a slight clearance. The manner of assembling said reactance coils and hollow tube 56 with shell parts 52 and 54 will be apparent from Figs. 5 and 6, and it will be understood that said coils and said tube 56 are secured in position between parts 52 and 54 which are fastened together in any suitable way as by a plurality of bolts (not shown) passing through the openings 58 in part 52 and aligned openings 60 in the companion part 54 of said laminated shell. It will be understood that the opening in hollow tube 56 is in longitudinal alignment with the central openings of the solenoids so that solenoid plunger 28 is movable longitudinally axially of the solenoid windings and of said reactance or choke coils. The first reactance coil R1 is positioned one and one-third the length of a solenoid winding from the adjacent end of the adjacent solenoid winding, in this case solenoid winding S3, and reactance coils R1, R2 and R3 are spaced from each other longitudinally of plunger 28 by a distance equal to the length of the solenoid winding. The axial length of each reactance coil is equal to one-third the axial length of a solenoid winding. The reactance or choke coils R1, R2 and R3 are connected in a circuit with electro-magnetically operated means or control relays A, B and C, said circuit also including a reversing relay D (Figs. 2, 3 and 17), said control relays being operable under the control of said reactance coils for energizing and de-energizing the windings of solenoids S1, S2 and S3, in the proper sequence, as will be hereinafter more specifically described in a more detailed explanation of the operation of this invention.

The control relays A, B and C are identical in construction and each of them is provided with two pairs of companion contacts, one pair of contacts being normally open and capable of carrying the current required by one solenoid, and the other pair of contacts being normally closed and used in the control circuit. These control relays are quick acting relays and are provided with means for adjusting armature clearance, contact gap, and spring tension. Since, as stated, these relays A, B and C are of the same construction, a description of one, in this case relay A, shown in Fig. 4 as well as in Figs. 2 and 3, will be sufficient, but it will be understood that any relay having the characteristics referred to may be utilized in lieu of the specific relays herein shown or described. The control relay comprises a coil 62 wound for alternating current and provided with an iron core 64 and with an armature 66 pivotally connected as indicated at 68 to core 64. Armature 66 is fixed to the bottom of an insulation member 70 which carries the movable normally open and normally closed contact members A1 and A2 of the control relay, these members being designated as A1 and A2, respectively, but it will

be understood that they are the same as the corresponding normally open and normally closed movable contacts B1 and B2, respectively, of relay B and the normally open and normally closed movable contacts C1 and C2, respectively, of relay C. Companion normally open and normally closed stationary contacts are shown at a1 and a2, respectively, for relay A; at b1 and b2, respectively, for relay B; and at c1 and c2, respectively, for relay C. The movable contacts A1 and A2 and the corresponding movable contacts of relays B and C, are not only carried by pivoted member 70 but are also movable with respect thereto to permit adjustment of the armature clearance and regulation of spring tension of said movable contacts when engaging their companion stationary contacts, respectively. For this purpose said movable contacts are each connected to a pin 72, the lower end of which passes loosely through the companion movable contact member and is secured to contact carrying member 70. Collar 74, slidable longitudinally of pin 72 near the lower end thereof, bears on the upper part of the companion movable contact member and is held resiliently against the latter by a compression spring 76. The upper end of spring 76 bears against a slidable collar 78 which can be adjusted longitudinally of pin 72 by a nut 80 threaded on the upper end of pin 72. The movable contact members are held against turning axially of pin 72 by screws 82 which pass through slots at the inner ends of said movable contact members, respectively, so that said movable contact members can move in relation to carrying member 70, as well as with the latter, for engaging the companion stationary contact members resiliently under the pressure of the companion springs 72, without limitation by the movement of armature 66 to its retracted position. A spring 84 holds the armature in its upper or retracted position, said spring being connected to contact carrying member 70. The clearance of armature 66 is adjusted by a screw 86 which is threaded through the top of the U-shaped strap 88 secured to the mounting insulation panel P. It will be understood that when the coil of the relay is de-energized spring 84 moves the armature 66 to its retracted position against the lower end of screw 86 and that by adjusting said screw in strap 88 the clearance of the armature is adjusted. The stationary contact members a1 and a2 are as here shown constituted by screws which are adjustable in insulation supports 90 and 92. The terminals for the movable contact members may be connected to the screws 82 while the terminals for the companion stationary contact members can be connected to the metal strips 94 which are secured to the companion insulation supports by nuts 96 in which the screws of the companion stationary contact members a1 and a2 are engaged.

The reversing relay D is a triple-pole double-throw, alternating current relay wound to operate by the line current. This relay has three pairs of normally open companion contact members and three pairs of normally closed companion contact members, the normally open movable contact members being indicated at D1, D3 and D5 and the normally open stationary contact members being indicated at d1, d3 and d5. The normally closed movable contact members are indicated at D2, D4 and D6 and the normally closed companion stationary contact members are indicated at d2, d4 and d6. This reversing

relay is constructed substantially in the same way as the control relays A, B or C and has a single coil 98 and a single armature 100 which operates all of the movable contact members of this relay, said armature being pivotally mounted in the same way as the armature 66 of the control relay and being fixed to a carrying plate 102 which is spring retracted in the same way as carrying plate 70. The carrying plate 102 of this relay mounts the movable contact members in the same way as in the control relays, and said movable contact members are spring pressed in the same way as the movable contact members of the control relays for resilient engagement with the companion stationary contact members. Said stationary contact members are of the same construction as the stationary contact members of the control relays and are mounted in substantially the same way, the normally open stationary contact members being adjustable in an insulation support 104 and the normally closed stationary contact members being mounted in an insulation support 106. The terminals for the movable contact members are connected thereto in the same way as in the control relays and the terminals for the stationary contact members are connected to the strips 108 which are the same as the contact strips 94 of the control relays. The clearance of armature 100 of the reversing relay is adjusted by a screw 110 which is in threaded engagement with the top of the strap 112 and engages contact carrying member 102 in the same way as the engagement of adjusting screw 86 with contact carrying member 70 of the control relays.

The operation of the above described apparatus will now be described with more particular reference to Figs. 11 to 17. Referring first to Fig. 17, it will be noted that each of the control relay windings 62 is connected in series with one of the reactance coils R1, R2, R3, so that the current flowing through the relay winding is governed by the impedance of the reactance or choke coil with which it is connected. The windings of the control relays and reactance coils are so matched that when a magnetic section 40 of plunger 28 is entered in the reactance coil, the inductive reactance due to the presence of said magnetic section in the reactance coil in addition to the inductive reactance due to the iron shell of the reactance coil is so high that the resultant current flowing through the relay is lower than the pick-up rating of the relay and the latter remains open at its normally open companion contacts A1, a1 in the case of relay A or at the corresponding normally open contacts B1, b1 in the case of relay B or the normally open contacts C1, c1 in the case of relay C. However, when the iron segment 40 is withdrawn from the reactance coil, the inductive reactance is lowered sufficiently to allow an increase in current which is sufficient to close the companion relay at its normally open companion contacts and to simultaneously open the normally closed companion contacts of said relay.

Referring now to Figs. 11 to 16, and assuming for the purpose of explanation that the solenoid windings and the reactance coils are stationary and that the solenoid plunger 28 is movable, Fig. 11 shows the position of plunger 28 after solenoid S2 has drawn magnetic section 40(e) completely into its winding. In this position, it will be noted, magnetic section 40(f) is partially entered in solenoid S3 at the right thereof while magnetic section 40(g) is partially entered into sole-

noid 1 at the left thereof. It is obvious that if solenoid S1 is next energized, the plunger will move to the right while on the other hand, if solenoid S3 is then energized the plunger will move to the left. We will now assume that plunger 28 is to move to the left as indicated by the arrow in Fig. 11.

Referring still to Fig. 11, it will be observed that magnetic section 40(h) of the plunger has left the winding of reactance coil R2, thus lowering the reactance of its circuit and closing relay B through normally closed contacts C2, c2 of relay C (Fig. 17) and contacts D6, d6 of relay D. When relay B closes, its normally closed contacts B2, b2 open circuit relay A and its normally open contacts B1, b1 close, thereby completing a circuit through solenoid S3 across the line terminals T1, T3 supplied with alternating current through the main switch MS from the lines L1 and L2. When solenoid S3 is thus energized it draws magnetic section 40(f) of the plunger into its winding and the plunger moves to the left, bringing the plunger to the position shown in Fig. 12. At this instant when plunger section 40(f) is completely entered in solenoid S3, the magnetic section 40(i) of the solenoid plunger is fully withdrawn from the reactance coil R3 lowering its reactance to minimum, so that the flow of current increases through said coil R3 passing through the latter and normally closed contacts A2, a2 of relay A and contacts D2, d2 of relay D, thus energizing the coil of relay C. When the coil of relay C is energized, its normally closed contacts C2, c2 open, thus disconnecting the coil of relay B. When relay B is disconnected its contacts B2, b2 close and a current of low value will flow through the reactance coil R1 and relay A in preparation for its closing operation, but at this time section 40(h) of the plunger is fully entered in reactance coil R1 causing maximum inductance which maintains the current at such a low value that said current is insufficient to energize relay A. On the other hand, the contacts B1, b1 of relay B open and disconnect solenoid S3 thus releasing the magnetic section 40(f) of the plunger. When relay C closes, its normally open contacts C1, c1 close thus connecting the winding of solenoid S1 across the line so that said solenoid S1 is energized and draws magnetic section 40(e) into said solenoid winding so that the movement of plunger 28 continues to the left as shown by the arrow in Fig. 12 bringing the plunger to the position shown in Fig. 13. Magnetic section 40(h) of the plunger has now left reactance coil R1 causing current to flow through contacts B2, b2 of relay B to the contacts D4, d4 of relay D and thus energizing the winding of relay A. When relay A is thus energized relay C is de-energized and the winding of solenoid S1 is likewise de-energized, thus releasing magnetic section 40(e) of the plunger and at this time the winding of solenoid S2 is energized thereby drawing in magnetic section 40(f) of the plunger bringing the plunger to the same position in relation to the solenoid and reactance windings as that illustrated in Fig. 11. The cycle thus far described then repeats itself, the plunger moving continuously to the left for the length of travel allowed by the length of the solenoid.

If movement of plunger 28 to the right is desired, the relay D is closed by closing the switch RS, switch RA (hereinafter more specifically referred to) being open. When switch RS is closed and switch RA is open, contacts D2, D4

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and D6 of relay D open, disengaging their companion contacts d2, d4 and d6 and contacts D1, D3 and D5 close engaging their companion contacts d1, d3, and d5, respectively. When this occurs the action, starting with the position of the parts illustrated in Fig. 14, takes place in the same way described above with reference to Figs. 11 to 13 but in the opposite direction, that is to the right as shown by the arrows in Figs. 14, 15 and 16. More particularly, the position of the plunger in Fig. 14 is the same as in Fig. 1. Magnetic section (h) is clear of reactance coils R1 and R2. In this case, the inductance of these reactance coils is minimum allowing maximum current to flow in either direction, but by reference to Fig. 17 it will be noted that when current flows through reactance coils R1, contacts B2, b2, D3, and d3, relay C is energized. When relay C is energized, its normally closed contacts C2, c2 open and prevent current from flowing through reactance coil R2, while its normally open contacts C1, c1 being closed, complete a circuit through solenoid S1 so that the latter draws section 40(g) of the plunger within its winding thereby causing the movement of the plunger to the right to the position illustrated in Fig. 15. It will be understood that said plunger continues to move to the right to the positions illustrated in Figs. 15 and 16 in the same manner as explained above with reference to Figs. 12 and 13, resulting in the movement of the plunger to the position illustrated in Fig. 14, which is the same relative position as that shown in Fig. 11, thus completing the cycle which is repeated, plunger 28 continuing to move to the right to the extent allowed by the length of the plunger until switch RS is opened. Accordingly, it will be understood that by opening and closing switch RS at the proper times, the plunger will reciprocate, moving alternately to the left, as illustrated in Figs. 11 to 13, and to the right as illustrated in Figs. 14 to 16.

The present invention makes provision for the automatic opening and closing of the reversing relay D. For this purpose, a relay E is connected in the circuit, as shown in Fig. 17, through the manually controlled switch RA, said relay being associated with a branch circuit having the normally open contacts E1, e1 and the normally closed contacts E2, e2, contacts E1 and E2 being movable and contacts e1 and e2 being stationary. The armature 114 of relay E controls companion relay contacts E3, e3, said last mentioned contacts being normally held open by a spring 116, contact E3 being a movable contact and contact e3 being a stationary contact. Contacts E1 and E2 are biased to open and closed positions, respectively, in any suitable way and are closed and opened, respectively, by operation of levers 118 and 120, respectively. It will be understood that levers 118 and 120 although shown at a short distance from each other will in actual practice be spaced at a distance approximately equal to the travel of plunger 28 (or of the solenoids S1, S2 and S3) in one direction so that said levers will be engaged at the end of the travel of the plunger (or of the solenoids) in either direction, thus alternately closing contacts E1, e1, and opening contacts E2, e2. It will be understood that when the automatic operation of the reversing relay D is desired under the control of relay E and its companion branch circuit, switch RS is opened and switch RA is closed. In the position of the parts illustrated in Fig. 17, relay D is de-energized as the contacts E3, e3 of relay E are open, said relay E being de-

energized. It will be observed that one side of winding 98 of relay D is connected by the wire 119 leading to the main line 121 connected to terminal T1 and that the other side of the relay winding 98 is connected by a wire 122 to a terminal T2 which connects with the other side 124 of the line, leading from the terminal T3 either through the line 126 controlled by the switch RS or through the branch line 128 controlled by the relay contacts E3, e3, or through the contacts E1, e1 and E2, e2. Branch line 128 connects line 124, through switch RA, to movable contact member E3 of relay E.

When the reversing relay D is to be energized automatically following the limit of travel of plunger 28 to the left, so that said travel will be reversed and take place in the right hand direction, as described above, automatically under the control of relay E and the associate branch circuit, switch RS is opened and switch RA is closed. It will be understood of course that the movement of the solenoid windings, and the casing 13 carrying the same, to the right is the equivalent of the movement of the solenoid plunger to the left. Accordingly, when casing 13 reaches the limit of its travel to the right, relay D is closed, that is, a circuit is completed through its winding 98, so that the movement of casing 13 will be reversed and take place to the left. For this purpose, the normally open contacts E1, e1 are arranged to be closed when casing 13, or a part connected thereto and movable thereby, reaches the limit of its travel to the right. This will occur when said casing engages lever 118 whereby to actuate movable contact E1 for engaging its companion stationary contact e1. When contacts E1, e1 are thus engaged, current passes from main line 124 through switch RA through contacts E1, e1 to wire 130 (which connects movable contact E1 to stationary contact e2) and then through the normally closed contacts e2, E2 and from the latter over the wire 132 to one side of the coil 134 of relay E, passing through said coil 134 and to the other main line 120 over the wire 136. Winding 134 is thus energized and operated to close the normally open contacts E3, e3 and current flows from line 124 over wire 128, through said contacts E3, e3 over wire 122 to one side of winding 98 of relay D and then over wire 118 to the other main line 120, thus operating the reversing relay D. At this time, current may also flow to the winding of relay D from the contacts E1, e1 over the wire 130 and over the wire 138 to wire 122, so that the winding 98 of relay D is energized instantaneously upon the closing of contacts E1, e1. However, a holding circuit through relay E is provided for maintaining the winding 98 of relay D energized until casing 13 or the part operated thereby reaches the limit of its movement to the left, at which time lever 120 is operated by the casing or by some other part movable thereby, whereby to disengage movable contact member E2 from its companion stationary contact member e2, thus breaking the circuit through winding 134 of relay E. When the winding of relay E is thus de-energized, spring 116 of relay E disengages movable contact E3 from the companion stationary contact e3, thus breaking the circuit through the winding 98 of the reversing relay D and restoring said reversing relay to its condition for the movement of the solenoid plunger to the left or the equivalent movement of the solenoid windings or casing 13 to the right. It

will be noted that the holding or locking circuit for relay E maintains the winding 134 of said relay energized from the time that switch contact lever 118 is disengaged to the time that switch lever 120 is engaged, current for energizing winding 134 being then supplied from line 124 over wire 128 through contacts E3, e3, wire 138 through normally closed contacts E2, e2 and wire 132, this holding circuit being broken when switch lever 120 is operated to disengage contact E2 from contact e2, thus resulting in de-energizing winding 134 and the opening of the circuit at contacts E3, e3, this circuit remaining open until contacts E1, e2 are closed when casing 13 again reaches the limit of its travel to the right.

Instead of utilizing the circuit illustrated in Fig. 17, the circuit shown in Fig. 18 may be used and in that case the control relays A', B' and C' instead of having one pair of normally open contacts and one pair of normally closed contacts as in the case of relays A, B and C will each have two pairs of companion normally open contacts. The operation of the apparatus with these relays in the circuit as illustrated in Fig. 18 will now be described, reference being had also to Figs. 11 to 16 in conjunction with Fig. 18. Assuming that the plunger is in the position illustrated in Fig. 11 and is to move to the left, as soon as the magnetic section 40(h) leaves reactance coil R2 an increase in the flow of current through relay B' takes place, thus closing said relay at both of its normally open contacts, the flow of current taking place from line 124 to one side of reactance coil R2 and from the other side thereof to the normally closed contacts D6, d6 of reversing relay D and from said contacts through the winding 62 of relay B' and from the latter to the other line 120. When relay B' is closed, current flows from line 120 through the companion contacts B'1, b'1 to the winding of solenoid S3 and from the latter to the other main line 124. At the same time, the other pair of normally open contacts B'2, b'2 of relay B places reactance coil R1 directly across the main lines 120 and 124 and short circuits relay A', the latter being in series with reactance coil R1 when contacts B'2, b'2 of relay B are open. Relay A' being thus short circuited is thus deenergized and opens at both pairs of its companion contacts A'1, a'1, and A'2, a'2, thus breaking the circuit through solenoid S2. This brings the plunger to the position illustrated in Fig. 12, at which time solenoid S1 is energized by the closing of relay C' at its companion contacts C'1, c'1 which occurs when relay A' was de-energized and opened at its contacts A'2 and a'2. It will be understood that in moving from the position illustrated in Fig. 11 to the position illustrated in Fig. 12, section 40(i) of the plunger is moved out of reactance coil R3, thus causing current to flow from line 124 through said reactance coil and from the latter to the contacts D2, d2 of relay D to one side of the winding 62 of relay C' and from the other side of said winding to the other main line 120, thus closing said relay at its contacts C'1, c'1 and completing a circuit from one main line 121 through said contacts C'1, c'1 to one side of the winding of solenoid S1 and from the other side of said winding to the other main line 124. At the same time, the contacts C'2, c'2 are closed and thereby throw reactance coil R2 directly across the main lines 121 and 124, short circuiting relay B', thus de-energizing the winding

62 of the latter so that it opens at both pairs of its companion contacts. When relay B' is opened the winding of solenoid S3 is de-energized and the parts are in the position illustrated in Fig. 13 following which solenoid S2 is to be energized. At this time section 40(h) of the plunger has left reactance coil R1 so that a flow of current takes place from line 124 through said reactance coil and from the latter to contacts D4, d4 of relay D to one side of winding 62 of relay A' and from the other side of said winding to line 121, thus energizing said relay and closing both pairs of the companion contacts of the latter. The closing of the contacts A'1, a'1 of relay A' completes a circuit through the winding of solenoid S2 from one line 121 through said contacts A'1, a'1 to one side of said solenoid and from the other side of said solenoid to the other main line 124. At the same time, contacts A'2, a'2 of relay A' close and short circuit the winding 62 of relay C', thus de-energizing said relay so that both of the pairs of contacts thereof open. This completes the cycle which is repeated along successive lengths of the plunger. When it is desired to move plunger 28 to the right, relay D is operated either by the closing of switch RS, switch RA being open for manual operation, or by opening switch RS and closing switch RA, for automatic reversing operation as described above with reference to Fig. 17, relay E and the branch circuit associated therewith being the same as in Fig. 17. When winding 98 of relay D is energized for operating said relay, the normally closed contacts D2, d2, D4, d4, and D6, d6 are opened and the normally open companion pairs of contacts D1, d1, D3, d3 and D5, d5 are closed. When said normally open contacts of relay D close, plunger 28 moves to the right, the solenoid windings are energized under the control of relays A', B' and C' in the same way as just described in explaining the movement of the solenoid plunger to the left except that the solenoid windings are energized in the order of solenoid windings S1, S3, and S2. It will be noted that the relays A', B' and C' are operated in the circuit under the control of reactance coils R1, R2 and R3 so that when one relay is energized the relay which was just previously energized is short circuited and is de-energized and thereby prepares the third relay to be energized as soon as the magnetic section moves out of the reactance coil which controls the operation of said third relay.

It will be understood that relays A', B' and C' may be of the same construction as relays A, B and C with the exception that both sets of contacts, being normally open, are at the same side of the pivot 68, namely at the side at which the contacts A1, a1 of relay A are positioned as illustrated in Fig. 4. This is illustrated in Figs. 19 and 20.

In accordance with the form of the invention illustrated in Figs. 21 to 27, transformers are utilized instead of the reactance coils, in conjunction with the plunger 28, as the current varying means for controlling the operation of the control relays A, B and C, the arrangement being such that the magnetic sections 40 of the solenoid plunger 28, by moving into and out of the transformer windings, vary the current induced in the transformer secondaries and thereby control the operation of the control relays A, B and C for controlling the energization and de-energization, in the proper sequence, of the

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windings of the solenoids S1, S2 and S3. In this form of the invention, the solenoid windings and the plunger 28 are of the same construction as described above and the solenoid windings have the same spaced relation longitudinally of the plunger as in the above described forms of the invention, and also in this form of the invention the axial length of the transformer winding is one-third the length of a solenoid winding, but in this form of the invention the transformers TR1, TR2 and TR3 are spaced apart longitudinally of the solenoid plunger 28 a distance equal to one-third of the length of a solenoid winding and transformer TR1, which is closest to the adjacent solenoid winding S3, is spaced from said solenoid S3 a distance equal to one and two-thirds the axial length of a solenoid winding. The transformers are preferably mounted in a laminated iron shell and on a non-magnetic tube like the tube 56 shown in Figs. 5 and 6, and the primary and secondary windings of said transformers are connected in the circuit as illustrated in Fig. 27, the primary windings PW of said transformers being connected directly across the main lines 120 and 124 and the secondary windings SW of said transformers being connected to the control relays as shown in said wiring diagram (Fig. 27).

The reversing relay D' which corresponds to the reversing relay D in the above described forms of the invention (Figs. 17 and 18) is substantially the same as said reversing relay D with the exception that relay D' is as illustrated in Fig. 27 a six-pole double-throw relay while relay D is a three-pole double-throw relay. It will be noted also that the reversing relay D' can be operated either by closing switch RS for manual operation, switch RA being open, or by closing said last mentioned switch for automatic operation, switch RS being open, as explained above in connection with Figs. 17 and 18. The normally closed companion contacts of reversing relay D' are indicated in Fig. 27 at D1, d; D3, d3; D5, d5; D7, d7; D9, d9; and D11, d11; while the normally open companion contacts of said relay are indicated at D2, d2; D4, d4; D6, d6; D8, d8; D10, d10; and D12, d12. Also it will be understood that all of the movable contacts are connected for operation in unison by the insulation rod DI which is connected to the armature 100' of this reversing relay.

The operation of the apparatus in accordance with this form of the invention as illustrated in Figs. 21 to 27 will now be described. First, it will be understood that, as in the circuit in which the reactance coils are used as part of the current varying means, the current in the transformer secondary is insufficient to operate the control relay when the nonmagnetic section of plunger 28 is entered in the transformer winding but increases to a value sufficient to operate the control relay when the magnetic section or iron core of the plunger is entered in said winding. Referring to Fig. 27 in conjunction with Figs. 21 to 26 and first with reference to Fig. 21, assuming that the solenoid plunger is to move to the left, as indicated by the arrow, when magnetic section 40(e) enters transformer TR1, the secondary current is increased and closes relay A through the normally closed contacts C2, c2 of relay C and through the normally closed contacts D1, d1, and D11, d11 of relay D'. When relay A closes, the normally closed contacts A2, a2 of said relay open, dropping out relay B, and the normally open contacts A1, a1 of relay A

being closed, solenoid S3 is energized and pulls plunger 28 to the left bringing it to the position shown in Fig. 22. At this point magnetic section 40(g) of the plunger enters transformer T3 causing an increase in the secondary current of said transformer and thereby closes relay C through the normally closed contacts B2, b2 of relay B and through contacts D7, d7 and contacts D9, d9 of relay D'. Upon the closing of relay C, the normally closed contacts C2, c2 of said relay open, thereby disconnecting relay A, which in turn de-energizes solenoid S3, and the normally open contacts C1, c1 of relay C close, thus energizing solenoid S1, which draws in magnetic section 40(h), moving plunger 28 to the left to the position shown in Fig. 23. At this position of the plunger, magnetic section 40(g) enters transformer TR2 causing an increase in current in the secondary of said transformer which causes relay B to close. When relay B closes, its normally closed contacts B2, b2 open, thereby disconnecting relay C and de-energizing solenoid S1 and closing the normally open contacts B1, b1, thus energizing solenoid S2. When solenoid S2 is energized, it draws in the magnetic section 40(f) of the plunger, which is then in the same relative position in respect to the solenoids as in Fig. 1. This completes the cycle which is repeated successively along the length of the plunger. It will be understood that the movement of the plunger to the right takes place upon the closing of either switch RS for manual operation, or switch RA for automatic operation, as described above with reference to Fig. 11 or to Fig. 18.

As illustrated in Figs. 2, 3 and 4, the controlling relays and the reversing relay are mounted on the insulation panel P within the casing 13, but it will be understood that said relays need not be mounted for movement with casing 13, but can be disposed on a panel remote from casing 13, for example, in a switch room and connected in the circuit with the solenoids and with the reactance coils by a movable cable. However, since the need for this movable cable is eliminated by mounting the relays for movement with casing 13, the presently preferred embodiment of said relays provides for mounting them in casing 13.

When, as here shown, the relays are mounted in casing 13, it is advantageous to provide for the mounting and removal of said relays as a unit in readily removable relation to the solenoid and reactance coils in said casing so that in the event of the necessity for repairs or adjustments which cannot be easily made or which require considerable time, the unit, comprising mounting panel P and the relays carried thereby, can be easily removed from the casing and if desired, immediately replaced by another similar unit. In this respect the construction and arrangement contemplated in accordance with the present invention makes provision for the quick mechanical securing of the unit in casing 30 and the quick electrical connection of the relays to the solenoid and reactance coil windings. First, it will be understood that the relays A, B, C and D are mechanically secured to mounting panel P in any suitable way, unnecessary to be described or illustrated. In order, however, to removably secure panel P in housing 13 and more particularly between channel irons 18, said insulation panel P has secured thereto, as illustrated in Figs. 2, 3, 28 and 29, a plurality of metal plates or bars 140, 141, 142 and 143 disposed in transversely spaced relation in the space between re-

lays C and D, and similar plates 144, 145 and 146 are secured to said panel P at points spaced longitudinally thereof near relays A, B and C, respectively. Said plates 140 to 146, inclusive, are of the same construction and each of said plates is secured to panel P by a bolt 148 which passes through said panel and is secured at the under surface of the latter by a nut 150, and to the lower end of said bolt an electric terminal member 152 is secured by a nut 154. Each of said plates 140 to 146 is also provided with a circular opening 156 for the slidable projection therethrough of a conducting stud here shown as a bolt 158. In the case of plates 140 to 143, inclusive, the companion bolts 158 are carried by an insulation plate 160 (Figs. 2, 28 and 29) which is secured to and below the upper flanges of channels 14 by screws or bolts 162. By reference to Fig. 28 it will be observed that spacing members 164 are disposed between the upper surface of plate 160 and the lower surfaces of the upper flanges of channel irons 14, so that plate 160 will be disposed in spaced relation to the lower surface of insulation panel P to provide a space for the wires leading to the terminals. Each bolt 158 is secured to plate 160 by a nut 166, and said bolt is secured to the companion metal plate at the upper surface of insulation panel P by a nut 168. An electric terminal 170 is secured to bolt 158 in any suitable way, as for example by the nut 166. It will be understood that when nut 168 is threaded down on bolt 158 for engagement with the companion metal plate at the top of insulation panel P, the latter is mechanically secured removably in the housing and at the same time said metal plate is electrically connected to the companion bolt 158 and to the terminal 170 carried by the latter. Each of plates 144 to 146 is similarly connected to panel P by a screw 148 the lower end of which carries a terminal 152 and said metal plates 140, 145, and 146 are mechanically and electrically connected to companion insulation plates 160A, 160B and 160C, respectively, each of which is secured at its opposite ends to the upper flanges of channels 14 in spaced relation in the same way as illustrated in Fig. 28 with reference to plate 160 to provide a space for the wiring connected to the terminals at the lower ends of bolts 148. It will be understood that by removing the nuts 168 from the bolts carried by plates 160, 160A, 160B and 160C, said panel can be easily removed through the top of housing 13 (top plate 22 having been removed) together with all of the wiring connected to the terminals 152 at the lower ends of bolts 148. It will be observed by reference to Fig. 3 that panel P also carries terminals T1, T2, and T3, referred to above with reference to the circuit diagram illustrated in Fig. 17. It will be understood that all of the terminals except the terminals connected to bolts 158 are carried by the insulation panel P, and from the wiring diagram illustrated in Fig. 17 the connections of said terminals in the circuit will be readily understood by those skilled in the art. Although relay E is not shown mounted on panel P, it will be understood that said relay may also be mounted on said panel, if desired, and when said relay is not mounted on said panel it is to be connected, when used, in the circuit by an appropriate cable.

It will be understood that the invention may be embodied otherwise than as herein disclosed and that in the illustrated embodiments certain changes in the details of construction and in the

arrangement of parts may be made without departing from the underlying idea of the present invention. Also, it will be understood that while I have illustrated the invention as used for operating an elevator door, the invention may be used for operating other devices and, more generally, the principle of the present invention may be applied to other purposes. Accordingly, I do not wish to be limited to the invention as herein specifically shown or described except to the extent which may be required by the scope of the appended claims.

Having thus described my invention, what I claim and desire to secure by Letters Patent is;

1. Apparatus of the character described comprising a motive device including a plurality of solenoid coils arranged in tandem, a solenoid plunger having alternate magnetic and non-magnetic sections arranged in tandem, said coils and plunger being mounted for relative axial movement, a plurality of reactance coils arranged in tandem and positioned in axial alignment with said solenoid coils, said reactance coils and said plunger being mounted for relative axial movement, said coils and said sections of the plunger being relatively positioned so that one of said magnetic sections is at least partly in one of said reactance coils when another of said magnetic sections is at least partly in one of said solenoid coils, and means operable under the control of said reactance coils during the movement of said plunger to connect one of said solenoid coils to a source of electric current and to disconnect another of said solenoid coils from said current source.

2. Apparatus of the character described comprising a motive device including a plurality of solenoid coils arranged in tandem, a solenoid plunger having alternate magnetic and non-magnetic sections arranged in tandem, said coils and plunger being mounted for relative axial movement, a plurality of reactance coils arranged in tandem and positioned in axial alignment with said solenoid coils, said reactance coils and said plunger being mounted for relative axial movement, said coils and said sections of the plunger being relatively positioned so that one of said magnetic sections is at least partly in one of said reactance coils when another of said magnetic sections is at least partly in one of said solenoid coils, and means operable under the control of said reactance coils during the movement of said plunger to connect one of said solenoid coils to a source of electric current and to disconnect another of said solenoid coils from said current source, and means for reversing the direction of relative movement between said plunger and said solenoid and reactance coils.

3. Apparatus of the character described comprising a motive device including a plurality of solenoid coils arranged in tandem, a solenoid plunger having alternate magnetic and non-magnetic sections arranged in tandem, said coils and plunger being mounted for relative axial movement, a plurality of reactance coils arranged in tandem and positioned in axial alignment with said solenoid coils, said reactance coils and said plunger being mounted for relative axial movement, said coils and said sections of the plunger being relatively positioned so that one of said magnetic sections is at least partly in one of said reactance coils when another of said magnetic sections is at least partly in one of said solenoid coils, and means operable under the control of

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said reactance coils during the movement of said plunger to connect one of said solenoid coils to a source of electric current and to disconnect another of said solenoid coils from said current source, and means for predetermining the direction of relative movement between said plunger and said solenoid and reactance coils.

4. Apparatus of the character described comprising a motive device including a solenoid having a coil and a plunger, means operable to connect and disconnect said coil to and from a source of electric current, and reactance means operable in response to relative movement of said coil and plunger for controlling the operations of said connect and disconnect means, and means for predetermining the direction of relative movement between said coil and said plunger.

5. Apparatus of the character described comprising a motive device including a solenoid having a coil and a plunger, means operable to connect and disconnect said coil to and from a source of electric current, and reactance means operable in response to relative movement of said coil and plunger for controlling the operations of said connect and disconnect means, and means automatically operative in response to a predetermined relative movement of said coil and plunger in one direction to reverse the direction of said relative movement.

6. Electro-magnetic motive means comprising a solenoid plunger having longitudinally extending magnetic and non-magnetic sections of equal length disposed successively along the length of the plunger in end to end relation, a plurality of solenoid windings disposed in spaced relation longitudinally of said plunger, said solenoid windings and said plunger being mounted for relative movement in the longitudinal direction of the plunger and relatively movable in said direction when said windings are energized, the axial length of each of said solenoid windings being equal to the length of one of said sections of the plunger, the distance between adjacent solenoid windings being about one third the axial length of a solenoid winding, and means for energizing said solenoid windings one at a time in succession.

7. Electro-magnetic motive means comprising a solenoid plunger having longitudinally extending magnetic and non-magnetic sections of equal length disposed successively along the length of the plunger in end to end relation, a plurality of solenoid windings disposed in spaced relation longitudinally of said plunger, the length of each of said windings being equal to the length of one of said sections of the plunger and the distance between adjacent solenoid windings being about one third the length of a solenoid winding, said solenoid windings and said plunger being mounted for relative movement in the longitudinal direction of the plunger and relatively movable in said direction when said windings are energized, and means operable for successively energizing said solenoid windings in one sequence for effecting said relative movement in one direction and for successively energizing said solenoid windings successively in a reversed sequence for effecting said relative movement in a reverse direction.

8. Electro-magnetic motive means comprising a solenoid plunger having longitudinally extending magnetic and non-magnetic sections of equal length disposed successively along the length of the plunger in end to end relation, a plurality

of solenoid windings disposed in spaced relation longitudinally of said plunger, the length of each of said windings being equal to the length of one of said sections of the plunger and the distance between adjacent solenoid windings being about one third the length of a solenoid winding, said solenoid windings and said plunger being mounted for relative movement in the longitudinal direction of the plunger and relatively movable in said direction when said windings are energized, and means for successively energizing said solenoid windings and for de-energizing the windings when the magnetic sections of the plunger are centered in said windings.

9. Electrical apparatus comprising a frame, an electrical device mounted on said frame, a panel, an electrical device mounted on said panel, and means for connecting said panel-mounted device to said first mentioned device, comprising a conducting-stud fixed to said frame and a conducting plate fixed to said panel and having an opening for the projection thereof through of said conducting-stud, and means for removably securing said stud to said plate whereby to secure said panel removably on said frame.

10. Apparatus of the character described comprising a motive device including a plurality of solenoid coils, a solenoid plunger having alternate magnetic and non-magnetic sections, said coils and plunger being mounted for relative movement, a plurality of control windings, means including magnetic parts movable by said plunger in relation to said control windings for varying the current therein, respectively, and means operable under the control of said windings for connecting one of said coils to a source of current and for disconnecting another of said coils from the source of current when said one coil is connected thereto.

11. Apparatus of the character described comprising a motive device including a plurality of solenoid coils, a solenoid plunger having alternate magnetic and non-magnetic sections, said coils and plunger being mounted for relative movement, a plurality of control windings, means including magnetic parts movable by said plunger in relation to said control windings for varying the current therein, respectively, and means operable under the control of said windings for connecting one of said coils to a source of current and for disconnecting another of said coils from the source of current when said one coil is connected thereto, and means automatically operative in response to a predetermined relative movement of said coils and plunger in one direction to reverse the direction of relative movement of said coils and plunger.

12. Apparatus of the character described comprising a motive device including a plurality of solenoid coils, a solenoid plunger having alternate magnetic and non-magnetic sections, said coils and plunger being mounted for relative movement, a plurality of control windings, means including magnetic parts movable by said plunger in relation to said control windings for varying the current therein, respectively, and means operable under the control of said windings for connecting one of said coils to a source of current and for disconnecting another of said coils from the source of current when said one coil is connected thereto, and means operable under the control of said last mentioned means for energizing one of said windings and for simultaneously de-energizing another of said windings.

13. Apparatus of the character described com-

prising a motive device including a plurality of solenoid coils, a solenoid plunger having alternate magnetic and non-magnetic sections, said coils and plunger being mounted for relative movement, a plurality of control windings, means including magnetic parts movable by said plunger in relation to said control windings for varying the current therein, respectively, and means operable under the control of said windings for connecting one of said coils to a source of current and for disconnecting another of said coils from the source of current when said one coil is connected thereto, said last mentioned means comprising a plurality of relays having windings in series with said control windings, respectively, for controlling the energization of said control windings during said connection and disconnection of said solenoid coils.

14. Apparatus of the character described comprising a motive device including a plurality of solenoid coils, a solenoid plunger having alternate magnetic and non-magnetic sections, said coils and plunger being mounted for relative movement, a plurality of control windings, means including magnetic parts movable by said plunger in relation to said control windings for varying the current therein, respectively, and means operable under the control of said windings for connecting one of said coils to a source of current and for disconnecting another of said coils from the source of current when said one coil is connected thereto, said last mentioned means comprising a plurality of relays having windings in series with said control windings, respectively, for controlling the energization of said control windings during said connection and disconnection of said solenoid coils, each of said relays controlling the circuit of the winding of another of said relays in series with one of said control windings and a pair of relatively movable contacts engageable with and disengageable from each other in response to energization of the companion relay winding for effecting said connection and disconnection of one of said solenoid coils.

15. Apparatus of the character described comprising a motive device including a plurality of solenoid coils, a solenoid plunger having alternate magnetic and non-magnetic sections, said coils and plunger being mounted for relative movement, a plurality of control windings, means including magnetic parts movable by said plunger in relation to said control windings for varying the current therein, respectively, and means operable under the control of said windings for connecting one of said coils to a source of current and for disconnecting another of said coils from the source of current when said one coil is connected thereto, and means operable under the control of said last mentioned means for energizing one of said windings and for simultaneously de-energizing another of said windings, and means automatically operative in response to a predetermined relative movement of said coils and plunger in one direction to reverse the direction of relative movement of said coils and plunger.

16. In apparatus of the character described comprising a motive device including a plurality of solenoid coils, a solenoid plunger having alternate magnetic and non-magnetic sections, said coils and plunger being mounted for relative movement, means for energizing and de-energizing said solenoid coils in predetermined sequence comprising a plurality of control windings, means operable in response to the relative movement of

said coils and plunger to vary the current in said windings, respectively, and means operable in response to the current in said windings for connecting and disconnecting the solenoid coils to and from a source of current.

17. In apparatus of the character described comprising a motive device including a plurality of solenoid coils, a solenoid plunger having alternate magnetic and non-magnetic sections, said coils and plunger being mounted for relative movement, means for energizing and de-energizing said solenoid coils in predetermined sequence comprising a plurality of control windings, means operable in response to the relative movement of said coils and plunger to vary the current in said windings, respectively, and means operable in response to the current in said windings for connecting and disconnecting the solenoid coils to and from a source of current, and means automatically operative in response to a predetermined relative movement of said coils and plunger in one direction to reverse the direction of relative movement of said coils and plunger.

18. In apparatus of the character described comprising a motive device including a plurality of solenoid coils, a solenoid plunger having alternate magnetic and non-magnetic sections, said coils and plunger being mounted for relative movement, means for energizing and de-energizing said solenoid coils in predetermined sequence comprising a plurality of control windings, means operable in response to the relative movement of said coils and plunger to vary the current in said windings, respectively, and means operable in response to the current in said windings for connecting and disconnecting the solenoid coils to and from a source of current, said last mentioned means comprising a plurality of relays each provided with contacts engageable with and disengageable from each other for effecting said connection and disconnection of the coil of a companion solenoid.

19. In apparatus of the character described comprising a motive device including a plurality of solenoid coils, a solenoid plunger having alternate magnetic and non-magnetic sections, said coils and plunger being mounted for relative movement, means for energizing and de-energizing said solenoid coils in predetermined sequence comprising a plurality of control windings, means operable in response to the relative movement of said coils and plunger to vary the current in said windings, respectively, and means operable in response to the current in said windings for connecting and disconnecting the solenoid coils to and from a source of current, said last mentioned means comprising a plurality of relays each provided with contacts engageable with and disengageable from each other for effecting said connection and disconnection of the coil of a companion solenoid, said relays being also provided with contacts engageable with and disengageable from each other for connecting and disconnecting said control windings to a source of current.

20. In apparatus of the character described comprising a motive device including a plurality of solenoid coils, a solenoid plunger having alternate magnetic and non-magnetic sections, said coils and plunger being mounted for relative movement, means for energizing and de-energizing said solenoid coils in predetermined sequence comprising a plurality of control windings, means operable in response to the relative movement of said coils and plunger to vary the current in said

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windings, respectively, and means operable in response to the current in said windings for connecting and disconnecting the solenoid coils to and from a source of current, said last mentioned means comprising a plurality of relays each provided with contacts engageable with and disengageable from each other for effecting said connection and disconnection of the coil of a companion solenoid, and means automatically operative in response to a predetermined relative movement of said coils and plunger in one direction to reverse the direction of relative movement of said coils and plunger.

21. In apparatus of the character described comprising a motive device including a plurality of solenoid coils, a solenoid plunger having alternate magnetic and non-magnetic sections, said coils and plunger being mounted for relative movement, means for energizing and de-energizing said solenoid coils in predetermined sequence comprising a plurality of control windings, means

operable in response to the relative movement of said coils and plunger to vary the current in said windings, respectively, and means operable in response to the current in said windings for connecting and disconnecting the solenoid coils to and from a source of current, said last mentioned means comprising a plurality of relays each provided with contacts engageable with and disengageable from each other for effecting said connection and disconnection of the coil of a companion solenoid, said relays being also provided with contacts engageable with and disengageable from each other for connecting and disconnecting said control windings to a source of current, and means automatically operative in response to a predetermined relative movement of said coils and plunger in one direction to reverse the direction of relative movement of said coils and plunger.

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