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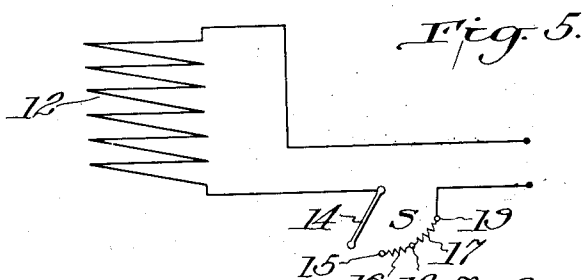
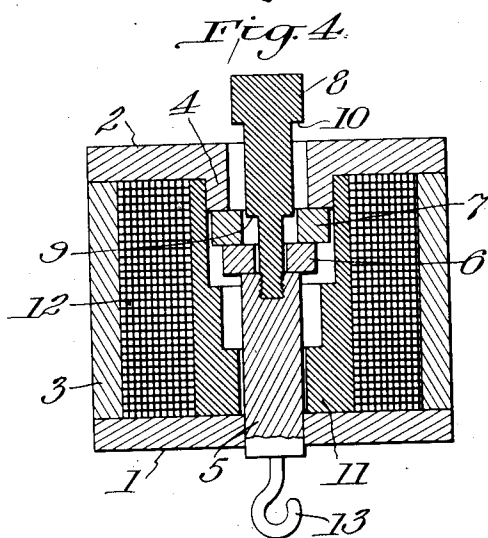
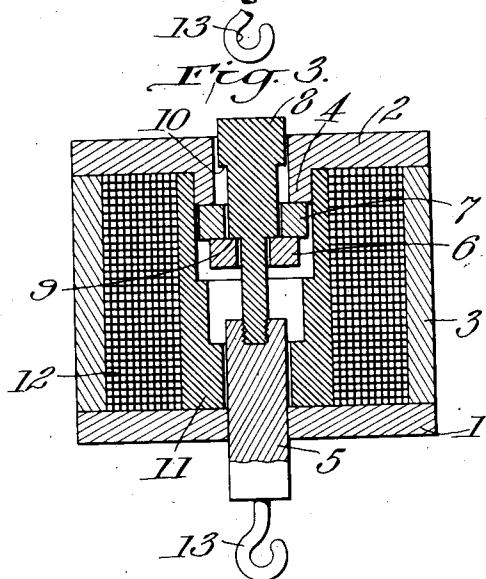
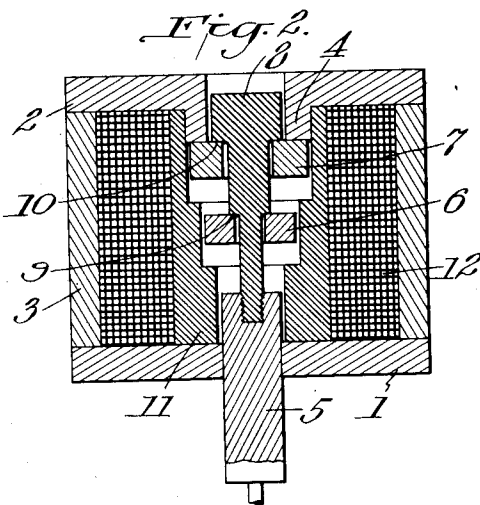
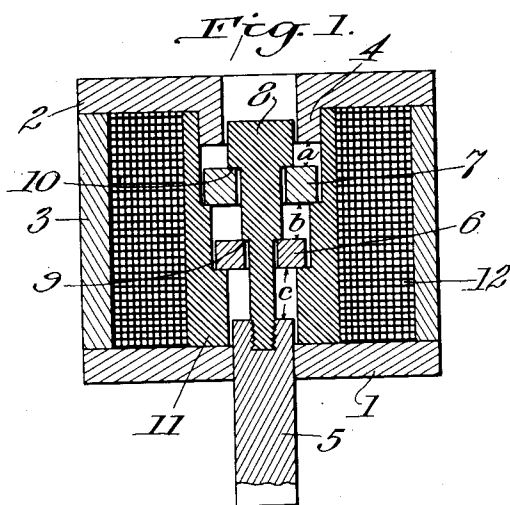
B. N. SOKOLOFF

1,817,592

ELECTROMAGNET

Filed April 8, 1929

2 Sheets-Sheet 1



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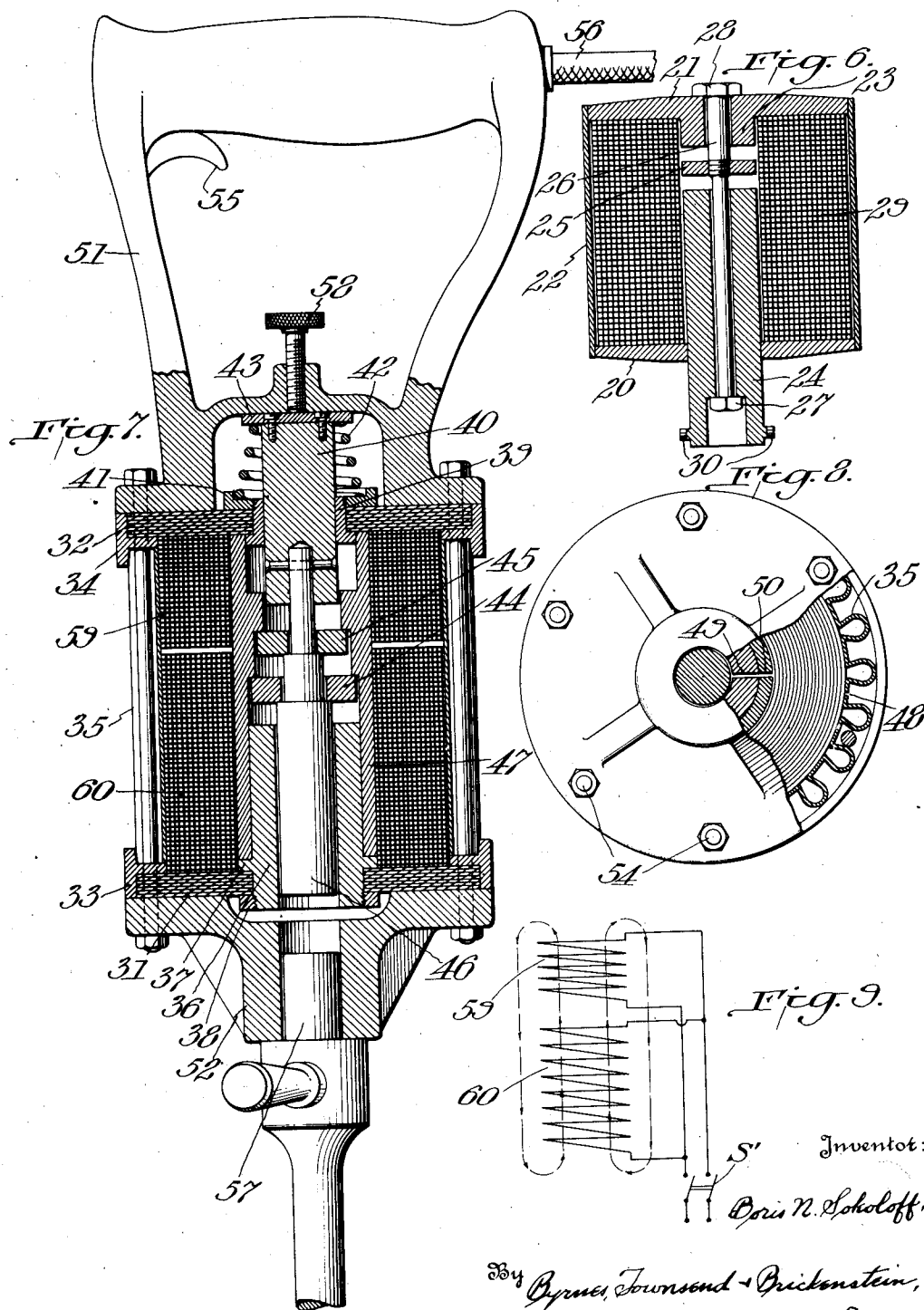
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UNITED STATES PATENT OFFICE

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ELECTROMAGNET

Application filed April 8, 1929. Serial No. 353,528.

This invention relates to electromagnets, and particularly to those of the open magnetic circuit type, i. e. to electromagnets in which the armature or armatures are separated from the core by an air gap when the solenoid is not energized.

While not limited in its application to any particular form of magnetic circuit or to any particular size of magnet, the invention is especially useful in connection with "power magnets" which may be employed for lifting relatively heavy loads or for operating such devices as electromagnetic hammers or presses.

This application is a continuation-in-part of my copending application Ser. No. 151,198, filed Nov. 27, 1926.

An object of the invention is to provide an electromagnet of such construction that the useful work, as compared to the ampere-turns and to the dead weight of the magnet, is materially higher than was obtainable with previously known constructions. A further object is to provide an electromagnet in which the armature may be given a step-by-step motion in accordance with the magnitude of the current traversing the solenoid. A further object is to provide an electromagnet in which, when the solenoid is not energized, a main armature and one or more auxiliary armatures are serially arranged along the path which the magnetic flux will take when the solenoid is energized. More specifically, an object is to provide an electromagnet of the type last stated in which the plurality of series air gaps in the magnetic circuit are progressively closed when the solenoid is energized, all armatures of the series being mechanically interconnected by one-way rigid connections which compel the main armature to move towards the zone of maximum tractive effort as the armature situated in such zone moves towards the core, or towards a supplemental armature which has been attracted to the core.

Further objects are to improve the mechanical and electrical construction of electromagnets employed for power purposes.

These and other objects of the invention will be apparent from the following speci-

cation, when taken with the accompanying drawings, in which

Figs. 1 to 4, inclusive, are longitudinal sectional views through an ironclad plunger magnet, Fig. 1 showing the moving parts in the respective positions which they occupy when the magnet is not energized, and the other views illustrating the progressive movement of the parts when the solenoid is energized;

Fig. 5 is a diagram of the electrical circuit of the magnet;

Fig. 6 is a longitudinal sectional view through another embodiment of the invention;

Fig. 7 is a fragmentary side view, with parts shown in longitudinal section, of an electric hammer embodying my invention;

Fig. 8 is an end view, with parts in section, of the hammer shown in Fig. 7;

Fig. 9 is a diagrammatic representation of the electrical and magnetic circuits of the construction shown in Figs. 7 and 8.

The ironclad plunger magnet which is illustrated in a somewhat diagrammatic manner in Figs. 1 to 4, inclusive, includes a yoke formed by the end plates 1, 2, and the cylindrical shell 3. The end plate 2 is provided with a cylindrical boss 4 which constitutes a stationary pole and the end plate 1 is apertured to receive the main armature 5. A pair of auxiliary armatures 6, 7 are serially arranged in the path of the magnetic flux between the pole 4 and the main armature 5. A rigid one-way connection between the armatures is provided by the stepped rod 8, which is fixed to the main armature 5 and has shoulders 9, 10 against which the armatures 6, 7, respectively, abut. The movement of the auxiliary armatures away from the pole 4 is limited by internal shoulders formed on the sleeve 11, which is fixed in place by and serves as a mechanical support between the two end plates 1, 2. The space between the sleeve 11 and the outer shell 3 receives the winding or solenoid 12 which is supplied with current from a suitable source to energize the magnet.

The stepped rod 8 and the shouldered sleeve 11 are formed of material of low per-

meability such as brass or non-magnetic steel. The several armatures and the yoke are formed of metals or materials of high permeability, such as soft iron or steel.

5 The main armature 5 slides within the aperture of the end plate 1 with a minimum clearance to maintain a magnetic connection of high permeability between these parts during the operation of the magnet.

10 For use as a lifting magnet, the main armature 5 is provided with a hook 13 or other suitable means for connection to the load.

Particular attention is directed to the fact that all of the armatures are serially arranged in the path which is taken by the flux when the solenoid is energized, and that, when the solenoid is de-energized, the armatures are separated from each other and from the pole by series air gaps of different lengths. The relative lengths of the air gaps when the magnet is de-energized are illustrated in Fig. 1. The gap a between the pole and the first auxiliary armature 7 is less than the gap b between the auxiliary armatures, and the gap b is in turn less than the gap c which lies between the auxiliary armature 6 and the main armature 5.

As shown on the circuit diagram, the winding 12 is energized from a suitable source through leads which include a switch S. When the switch arm 14 is on the open contact, as shown in Fig. 5, the solenoid is not energized, and the weight of the armatures will cause the several parts to take the positions illustrated in Fig. 1. When the switch arm is moved to contact 15 of switch S, the supply of current is through the series resistances 16, 17, and the flux which is established will be sufficient, for a predetermined load, to move the auxiliary armature 7 into contact with the pole 4, i. e., into the position shown in Fig. 2. As the armature 7 moves to close the air gap a , its engagement with the shoulder 10 of the rod 8 causes the main armature 5 to move upwardly through a distance equal to the length of the gap a . The armature 6 is attracted toward the pole 4 and the intervening armature 7, but the second air gap will not be closed when the load is of the order of that of the maximum weight which can be lifted when the solenoid is supplied with current through the series resistances 16 and 17.

Upon moving the switch arm 14 to contact 18, the flow of current through the winding 12 is increased and the correspondingly increased flux will establish a tractive force sufficient to move the armature 6 to close the second air gap b . The parts then occupy the position illustrated in Fig. 3. Although the increased flux may be sufficient to close the second air gap, the weight acting upon armature 5 may be such that the third air gap c will not be closed. Upon cutting out the remaining resistance 17 by moving the switch

arm 14 to contact 19, the current is increased and the increased magnetic flux will be sufficient to establish such traction that the main armature will move to close the remaining air gap. The several parts will then occupy the relative positions shown in Fig. 4.

The range of movement of the main solenoid 5 is of course equal to the sum of the three air gaps. An electromagnet of substantially the same construction but having a single armature movable over the same range will exert a materially smaller tractive force, since its traction is exercised over the entire air gap. As indicative of the substantial increase in tractive force which may be obtained in accordance with the present invention, the following data is given with reference to plunger electromagnets one of which was constructed in accordance with the previously known practice and one of which embodied the invention. The stationary iron parts were of identical construction in both magnets and the windings were also identical, being designed to give about 7500 ampere-turns at 110 volts. Both plungers were movable through 0.75 inch, but the moving system of one magnet was divided into a main armature and two auxiliary armatures, as described above. The dead weight of the plungers of the two magnets was the same. The useful weight which could be raised by the electromagnet having a plunger of the usual construction was 14.5 pounds, while the useful weight raised by the magnet embodying the present invention was 25.5 pounds. In designing the electromagnets, the curve given in the "Electrical Engineer's Handbook," H. A. Foster, 1918 edition, at page 129, was used as a guide, and it will be seen that the results obtained correspond closely to the respective points of the curve for the whole and one-third of the air gap.

The step-by-step operation of the magnet permits the controlled actuation of such devices as railway signals, multi-point switches, changeable indicators, and other apparatus in which an indicator or an operating arm is movable into any one of a plurality of positions. For many purposes, however, the step-by-step operation is not essential, and the regulating switch S or other control element may be replaced by other suitable switching devices, and the series air gaps may all be of the same length, or their relative lengths may be other than that required for step-by-step operation.

In Fig. 6 I have illustrated another embodiment of the invention. The magnet is of the plunger type and includes end plates 20, 21 and an enclosing shell 22. As in the previous construction, one end cap is provided with an annular lug 23 which forms a stationary pole for cooperation with the main armature 24 and the auxiliary armature 25. These series elements of the magnetic cir-

cuit are all formed of material of high permeability. The one-way connection between the armatures is provided by a non-magnetic rod 26 upon which the auxiliary armature 25 is threaded, the rod extending beyond the auxiliary armature and through the main armature 24. The outer end of the main armature is counterbored to receive the nut or other headed fastener 27 which rests against the radial surface at the end of the counterbore. The opposite end of the rod 26 carries a nut 28 which cooperates with the end plate 21 to limit the movement of the armatures away from the coil when the winding 29 is de-energized. The outer end of the main armature 24 is provided with suitable means for connection to the mechanism which is to be operated, such means being, for example, the lugs 30.

In Figs. 7, 8 and 9, the invention is illustrated as embodied in an electric hammer. The general arrangement of the elements of the magnetic system is substantially the same as in the magnet shown in Fig. 1. The end plates 31, 32, are preferably formed of a plurality of thin sheets or laminations of material of high permeability, such as soft iron or steel. The laminations fit within the annular rings 33, 34, respectively, which are preferably of T-shape in cross-section, the laminations resting within one annular recess of the rings and the opposite recess providing a seat for the corrugated shell 35. As illustrated in Fig. 8, the shell 35 is formed of a thin lamination which is so corrugated that a substantial part of the shell is in close contact with the solenoid, and the intervening ribs not only strengthen the shell but provide large radiating surfaces. The corrugated construction has the further advantage that, for a given cross-sectional area of magnetic material, the thickness of the shell may be materially reduced since the peripheral length of the corrugated shell will be much greater than the circumference of a plain cylindrical shell. For example, the peripheral length may be approximately three times the circumference of a cylindrical shell, and when this is the case, the corrugated shell may be formed of sheet metal of one-third the thickness which would be required for the plain shell. The stationary pole piece comprises a tubular member 36 having a peripheral flange 37 which abuts against the inner face of the laminated plate 31 and cooperates with the nut 38 to retain the pole in position. The end plate 32 is provided with a flanged sleeve 39 which forms a guide for the main armature 40, the guide 39 being secured in place by the flanged nut 41. A conical spring 42 is seated on the flanged nut 41 and bears against the cap 43 which is carried by the main armature 40, to move the main armature 40 and the auxiliary armatures 44, 45 away from the pole 36 when the

magnet is de-energized. The armatures are interconnected by the shoulder rod 46 of non-magnetic material, and the movement of the respective auxiliary armatures away from the pole 36 is limited by internal shoulders 70 on the sleeve 47 which is also formed of material of low permeability.

To prevent the formation of eddy currents and to avoid transformer action, the shell 35, pole 36 and sleeve 47 are provided with longitudinal slots, as indicated at 48, 49 and 50, respectively.

The parts of the magnetic circuit are held in proper relative position and the handle 51 and tool socket 52 are secured to the magnetic structure by bolts 54 which extend longitudinally through the assembly. The handle is preferably of the pistol grip type, and a trigger 55 is provided for actuating the switch, not shown, which is arranged between the flexible conduit 56 and the windings of the magnet. The tool socket 52 is provided with a central aperture to receive and guide the shank 57 of the tool or tool holder. The blow of the hammer is delivered to the tool shank 57 by the rod 46 and the length of the stroke may be adjusted by the screw 58 which limits the return movement of the main armature 40.

The spring 42 is of such strength that the weight of the moving system and the residuary magnetic traction will not prevent the return stroke of the armatures and the associated connecting rod 46 when the hammer is held in upright position, as illustrated in Fig. 7.

In the previous constructions, the springs employed to return the plunger have been relatively heavy, the usual practice having been to employ a spring of such strength that the return stroke was made in substantially the same time as the power stroke. In accordance with the present invention, the spring is relatively light and the return stroke requires a materially longer period than the power stroke. The loss of energy due to the use of a spring is therefore materially reduced and the energy of the blow is increased. In the prior devices, the total time interval of an operating cycle was divided substantially symmetrically by the period of the power stroke and the period of the return stroke, while in accordance with the invention and due to the use of a lighter spring, the time interval is asymmetrically divided and the power stroke occupies a relatively small part of each cycle.

As shown in the circuit diagram of Fig. 9, the solenoid includes two windings 59, 60 which are connected in parallel across the source of current supply but which are serially arranged in the magnetic circuit. The number of turns in the coils 59 and 60 are not equal but both coils are traversed by the same magnetic flux, the path of the flux be-

ing indicated in Fig. 9 by the arrows. When the switch S' is opened, the same number of lines of force will cut both coils, and the counter electromotive forces thus generated in the coils will be in direct proportion to the number of turns in the respective coils. Since the resultant counter electromotive force formed by the two unequal windings will be a function of the differences of the number of turns in the two coils, the sparking and/or arcing at the contacts of the switch will be minimized.

This reduction in the sparking by the use of two electrical windings in parallel will of course be accompanied by a delay in the return of the armature since there is a decrease in the effective counter electromotive force. For any given electromagnetic tool or machine, the weight of the moving system and the rate of operation are factors which must be considered in designing the double winding. For relatively high speed, of course, the double winding may be undesirable because of the slowing down of the rate of return of the armature. In such cases, I may, of course, employ the usual condenser systems for reducing sparking contacts. To operate the hammer continuously, there is provided an interrupting or control device, additional to the main switch, which may, if desired, be incorporated in the hammer.

The relatively great tractive power may be obtained with various forms of magnets by the provision of a plurality of armatures which are so arranged that one of the armatures is located in the zone of maximum tractive effort and that the main armature which actuates the load is connected to the other armature or armatures by a rigid one-way connection which insures movement of the main armature when the armature in the zone of maximum tractive effort moves toward the core. When a plurality of intermediate armatures are employed, each of such auxiliary armatures successively enters the zone of maximum tractive effort as an armature adjacent thereto moves to close the gap over which the maximum effort was previously exerted. The rigid connecting means may take various forms other than that of the stepped rod which is described above, the principal requirements being that the tractive effort of each auxiliary armature be transmitted to the main armature, that the connecting rod, link or the like, will slide with relation to each auxiliary armature as the latter engages the core or an adjacent armature, and that the connecting means be formed of material of low permeability.

When the armature is of the plunger type or is pivoted upon the yoke, the connection between the armature and yoke is preferably of such form that the magnetic contact remains closed throughout the range of movement of the armature. In all practical con-

structions, and appreciable clearance is of course required to permit the relative movement of the armature, but the gap which is introduced at this point in the magnetic circuit may be reduced to a minimum when provision is made for lubrication of the parts.

When a step-by-step operation of the magnet is desired, an increased range of movement for one or more of the steps may be provided by so proportioning the relative lengths of the air gaps that two of the gaps will be closed for each increase in the current strength.

It is therefore to be understood that the embodiments of my invention which are above described are illustrative of the invention, but that the invention is not limited thereto. Many changes may be made in the several parts, their relative size, shape and arrangement, without departing from the spirit of my invention as set forth in the following claims.

I claim:

1. In an electromagnet, the combination with a solenoid, of a core, a movable auxiliary armature disposed in the path of substantially the entire flux established upon energization of said solenoid, a main armature normally having only a portion thereof within the path of substantially the entire flux said armatures being separated from each other and from said core by series air gaps when the solenoid is not energized, and connecting means of low permeability for causing the main armature to move into the flux path as the auxiliary armature is moved toward the core by the energization of the solenoid.
2. The invention as set forth in claim 1 in combination with stop means for separating said armatures when said solenoid is de-energized.
3. In an electromagnet the combination with a solenoid, of a core, a plurality of auxiliary armatures serially arranged in the path of substantially the entire flux established upon energization of said solenoid, a main armature normally extending only partly into the path of substantially the entire flux, said armatures being normally spaced from one another when said solenoid is de-energized, and connecting means of low permeability for causing said main armature to be drawn further into the flux path when any of said auxiliary armatures is moved toward said core by the energization of the solenoid.
4. The combination with a solenoid of a plurality of auxiliary armatures, a main armature and connecting means of low permeability between said armatures, said means including a member extending through said auxiliary armatures and engaging the same from one direction only.
5. In an electromagnet, a solenoid, a core,

a plurality of normally spaced armatures to provide a plurality of serially arranged air gaps therebetween, said armatures being serially arranged with respect to the flux from said core, said air gaps being smaller between the armatures adjacent said core than between armatures further removed from said core and a one-way connecting means between said armatures having telescopic movement through said auxiliary armatures.

6. In an electromagnet, the combination with a solenoid of a main armature, a plurality of auxiliary armatures and means effective in one direction only for connecting said auxiliary armatures in mechanical parallel with said main armature.

7. In an electromagnet, a stationary core, a main armature normally spaced from said core, a secondary armature between said core and said main armature and normally spaced from said core and said main armature, said armatures being serially arranged with respect to the working flux of the electromagnet, and means secured to the main armature and having a shoulder for engagement by the secondary armature to thereby move the main armature toward the said core when said secondary armature is attracted thereby.

8. In an electromagnet having a point of maximum holding power, a plurality of normally spaced armatures to provide a plurality of serially arranged air-gaps therebetween, said armatures being serially arranged with respect to the flux of said electromagnet from said point of maximum holding, and a one-way connection between all said armatures, said connection including a plunger secured to the armature furthest from said point of maximum holding, and having shoulders cooperating with each intermediate armature.

9. In an electromagnet, a solenoid, a core, a main armature, a plurality of auxiliary armatures and a connecting member fastened to said main armature and having shoulders engageable from one direction by said auxiliary armatures.

10. In an electromagnet, a solenoid, a core, a main armature, a plurality of auxiliary armatures and a connecting member fastened to said main armature having shoulders engageable from one direction by said auxiliary armatures, and relatively stationary shouldered means on said solenoid for spacing said auxiliary armatures when said solenoid is de-energized.

11. In combination, a solenoid, a main armature, auxiliary armatures and connecting means of low permeability secured to said main armature and engageable in only one direction by said auxiliary armatures and freely movable with respect to said auxiliary armatures in the other direction.

12. In combination, a solenoid, a main arm-

ature, auxiliary armatures, connecting means of low permeability secured to said main armature and engageable in only one direction by each of said auxiliary armatures and freely movable with respect to said auxiliary armatures in the other direction, and relatively stationary means cooperating with said connecting means and said armatures to space said armatures when said solenoid is de-energized.

13. In an electromagnet having a point of maximum holding power, a plurality of normally spaced armatures to provide a plurality of serially arranged air gaps therebetween, said armatures being serially arranged with respect to the flux of said electromagnet from said point of maximum holding, and a one-way connection between all said armatures, said connection including a plunger secured to the armature furthest from said point of maximum holding, and having shoulders cooperating with each intermediate armature, to effect movement of said furthest armature as each intermediate armature moves towards said point of maximum holding power.

14. The invention as set forth in claim 13, in combination with means for limiting the movement of each of said armatures away from the point of maximum holding power.

15. In an electromagnet of the ironclad plunger type, a solenoid, an armature, end plates comprising laminations extending normal to the axis of movement of said armature, and means including a corrugated shell completing the magnetic circuit between said laminated end plates.

16. The invention as set forth in claim 15 wherein the corrugations of said shell provide a series of surfaces in contact with said solenoid, the respective portions of said shell between said contact surfaces constituting heat-radiating ribs.

17. In an electromagnet, a plurality of elements of high permeability constituting a path for the flux, two windings having an unequal number of turns, and circuit connections for arranging said windings in parallel across a source of current and in series-aiding relation with reference to the flux, whereby the resultant counter electromotive force established when the current is interrupted is a function of the difference in the number of turns in said windings.

18. In an electromagnet, a solenoid, an armature, and a corrugated lamina of magnetic material adjacent said solenoid and constituting a portion of the magnetic circuit, the corrugations of said lamina providing a series of surfaces in contact with said solenoid, the respective portions of said lamina between said contact surfaces constituting heat-radiating ribs.

19. In an electromagnet, a solenoid, an armature, and a corrugated lamina of mag-

netic material adjacent said solenoid and constituting a portion of the magnetic circuit, said lamina having a slot extending therethrough in a direction parallel to the direction of the flux.

20. In an electromagnet, the combination with a solenoid, and a yoke comprising two equipotential surfaces, of a main armature, a plurality of auxiliary armatures disposed between said main armature and at least one of said equipotential surfaces, said armatures and said yoke constituting a substantially closed path of high permeability when said solenoid is energized, and means mechanically connecting said armatures, said means being effective when said solenoid is deenergized to maintain at least a portion of each of said armatures in the path of substantially the entire flux established upon the energization of said solenoid.

In testimony whereof, I affix my signature.
BORIS N. SOKOLOFF.

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