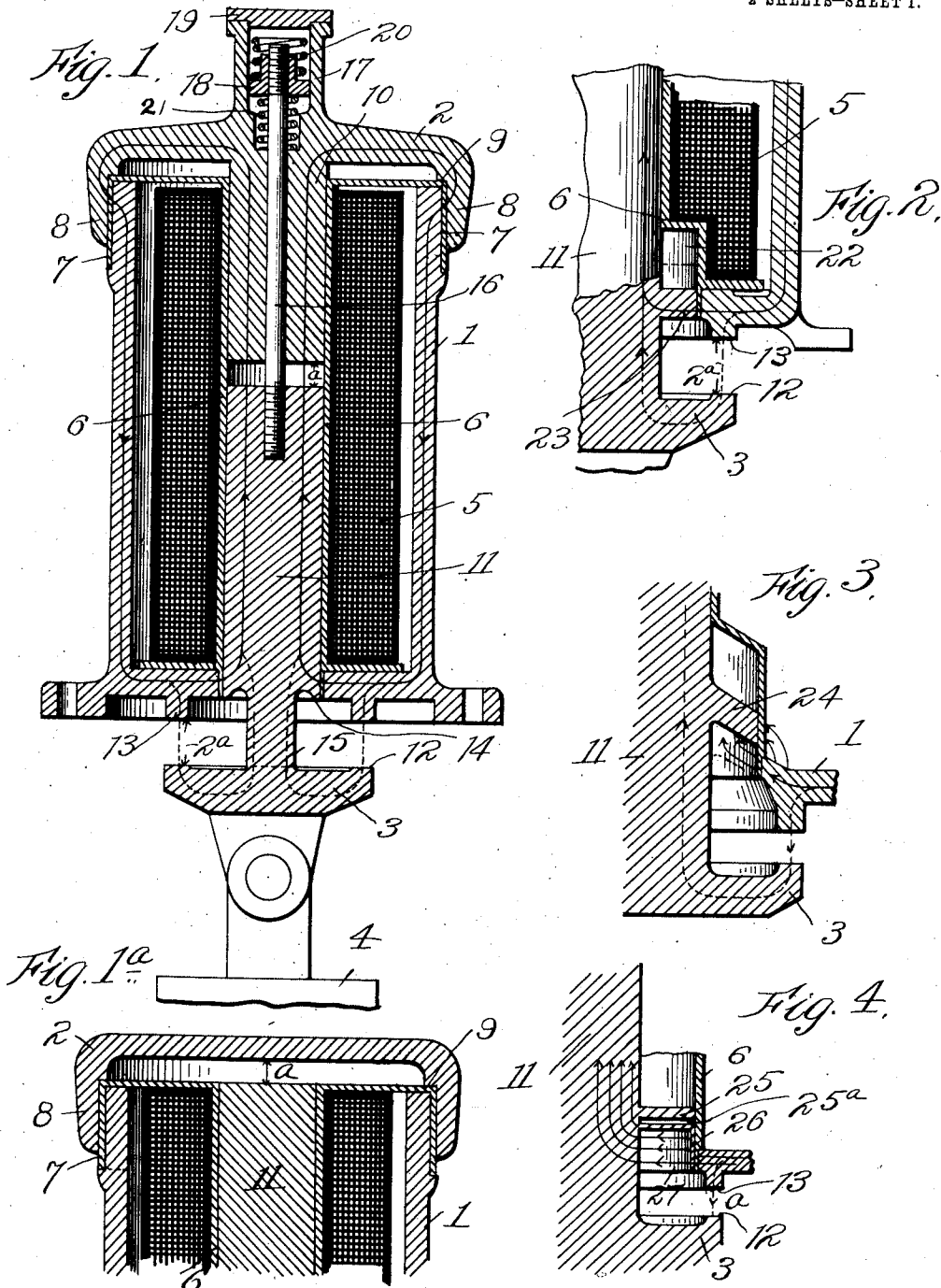


986,216.

Patented Mar. 7, 1911.

2 SHEETS—SHEET 1.



Witnesses:
H. H. Knight
H. A. P. Panke

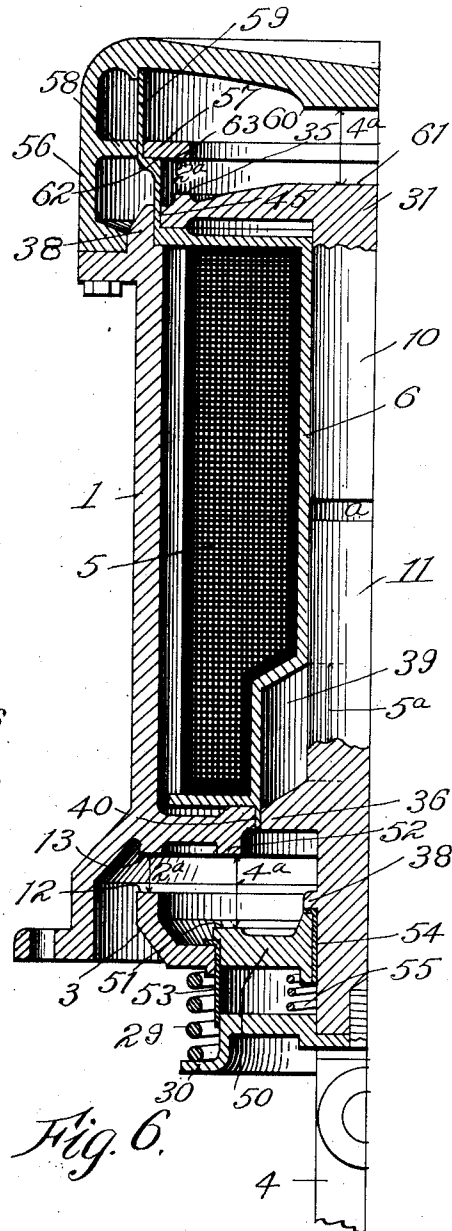
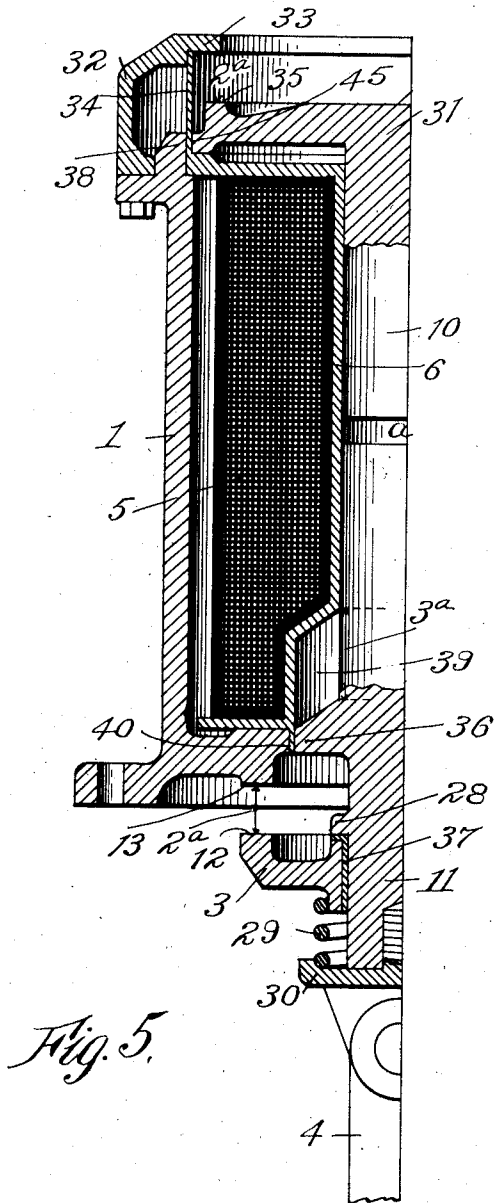
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By his Attorneys Knight & Poth

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LIFTING MAGNET.
APPLICATION FILED APR. 8, 1910.

986,216.

Patented Mar. 7, 1911.

2 SHEETS—SHEET 2.



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HEINRICH POTH, OF WILKINSBURG, PENNSYLVANIA.

LIFTING-MAGNET.

986,216.

Specification of Letters Patent.

Patented Mar. 7, 1911.

Application filed April 8, 1910. Serial No. 554,234.

To all whom it may concern:

Be it known that I, HEINRICH POTH, a subject of the German Emperor, and residing in the city of Wilkinsburg, State of Pennsylvania, have invented certain new and useful Improvements in Lifting-Magnets, of which the following is a full and clear specification, various forms of reduction to practice being illustrated in the accompanying drawings and the novel features of my invention being more fully pointed out in the annexed claims.

My invention relates to lifting or pull magnets provided with an armature the movement of which through a predetermined air gap is utilized to perform work such as for instance operating brakes, switches or the like. Magnets of this general type are old in the art and are employed in many varying forms for the purposes above stated. However, the disadvantage of this type of magnet as heretofore employed is that many times the amount of electrical energy must be expended than is necessary to hold the armature attracted under load in order to produce sufficient pulling power in the armature to attract the armature when it is farthest away from the magnet core; in other words, when the air gap between the armature and the magnet is the largest. The reason for this is that when such gap is the largest the path of the electro-magnetic lines of force through the air is the longest, and in order to drive a sufficient number of lines of force through this large air gap a number of ampere turns must be employed which is far in excess over the number of ampere turns necessary to lift the same load for instance when the armature is only a very short distance away from the magnet. This obviously entails an excessive amount of copper for the winding and in turn requires an excessive amount of energy which is uselessly expended after the armature has been attracted. On the other hand, it is highly desirable to have magnets with a large lifting stroke inasmuch as all the mechanism heretofore employed to transform the small stroke of the ordinary magnet into the stroke of desired length, is avoided thereby.

In my novel lifting magnet, the stroke of the armature may be of any desired length, of course within reasonable limits, by reason of the subdivided stroke which I employ,

through which the air gap traversed by the lines of force is limited to such a small space that only a fraction of the ampere turns is required to attract the armature through this small gap than is necessary to attract the armature through the whole stroke in the ordinary type of magnet.

I have illustrated in the accompanying drawings a number of preferred forms showing at the same time how the stroke of the armature may be subdivided once, twice or any desirable number of times, to form air gaps of desirable shortness.

In these drawings: Figure 1 is a vertical sectional elevation of a lifting magnet having its stroke subdivided into two small strokes. Fig. 1^a is a modification of the upper magnet portion shown in Fig. 1 showing the gap *a* located near the top of the casing. Figs. 2, 3 and 4 are modifications of the lower portion of the magnet shown in Fig. 1, only the lower right hand portion of the magnet being shown in these figures. Fig. 5 is a modification showing how the main stroke of the armature may be subdivided into three sub-strokes, the illustration showing only the left half of the sectional elevation of the structure, and Fig. 6 is a modification showing how the main stroke of the armature may be subdivided for instance into 5 sub-strokes, this figure also showing only the left half of the sectional elevation.

Referring to Fig. 1, 1 is the magnet housing made of magnetic material to form the outside path for the lines of force. It may be preferably round as shown. 2 is the yoke to be described hereinafter in detail and 3 is the armature to which the load 4 is attached in suitable manner. Within housing 1 is disposed the magnet coil 5 suitably insulated and mounted on a spool 6 of non-magnetic material which is fastened to housing 1. Spool 6, as shown in the figure, extends across the top and also downward on the outside of housing 1, as shown at 7, for the purpose of preventing an immediate contact between the downward extending portion 8 of the yoke 2 and housing 1. However, this layer 7 of non-magnetic material and also the lower end of the inner part, which runs through the bottom of housing 1, is of sufficient thinness so as not to form a gap of appreciable size and thus an undue obstruction for the path of the lines of force. While in the drawing spool 6 is shown as

one piece, for instance being a casting, it just as well may consist of 2 or more pieces, to suit the particular requirements and convenience in construction. Thus yoke 2, which normally rests with a shoulder 9 on the upper side of the spool 6, is permitted to move upward without undue friction between the housing 1 and portions 8 of the yoke which would exist in case of a direct contact between portions 8 and housing 1. Yoke 2 has in its center a core 10 which may extend partway down into coil 5 as shown in Fig. 1, thus forming part of the inner core of the electromagnet or as shown in Fig. 1^a yoke 2 may extend straight across the top of the magnet without a central core detent. Another integral part of the armature is core 11 which extends upward into coil 5 such distance that when the magnet is deenergized and the armature in the "off" position, a gap a is formed between cores 10 and 11 (in Fig. 1^a between core 11 and yoke 2). The armature portion 3 has preferably the form of a disk, and corresponding in size with the rim 12 of this disk an annular flange 13 is provided at the bottom of housing 1. In the deenergized position shown in Fig. 1, the distance between rim 12 and flange 13 is preferably double the size of gap a previously mentioned and equal at the same time to the total stroke of the whole armature. If now the magnet is energized the lines of force will take the path indicated by the arrows in Fig. 1, in full lines, this path being the one of least resistance at that time, whereas only few lines of force will travel the path indicated in dotted lines owing to the large air gap 2^a in this path. Therefore at this moment core 11 is the actual armature of the electro-magnet, this core being then attracted by core 10 whereby the load is lifted a distance equal to the gap a . While this takes place the gap between rim 12 of armature 3 and flange 13 is gradually reduced to a and the lower rim 14 of core 11 which is formed by the neck 15 connecting core 11 with armature 3, is also gradually traveling the distance a , as indicated in dotted lines. The result of this is that at the point where the lines of force formerly entered from casing 1 into core 11 gradually a comparatively large air gap is formed which surrounds neck 15 of core 11 and which offers a considerable resistance to the lines of force and which is greater than the resistance offered now by the gap between rim 12 and flange 13 which has decreased gradually to the size of gap a . Therefore the lines of force will gradually cease flowing from housing 1 directly to core 11, but at the same time the flux will increase in the path indicated in dotted lines in Fig. 1 from housing 1 to armature 3 across the air gap and thus tend to lift armature 3 against annular flange 13. It will

be clearly seen that thus the total magnetic pull exerted on armature 3, may be the same or about the same in all positions of the armature 3 during this first period a of the stroke just described. Armature 3 with core 11 is free to move upward because yoke 2, as previously mentioned, is free to slide upward, extensions 8 during this upward movement extending over housing 1 still sufficiently to not materially decrease the area through which the magnetic flux passes through yoke 2 into housing 1. Inasmuch as the upward movement of yoke 2 is at right angles to the direction of the magnetic flux at the point where the flux enters from extension 8 into housing 1, comparatively little magnetic resistance is encountered against the upward movement of yoke 2. Thus after armature 3 has now been fully attracted it will be seen that the total distance which the armature has lifted the load is equal to the stroke 2^a and still at no time lines of force were compelled to travel through an air gap larger than a in order to attract the armature. From the foregoing it will be seen that while with the magnet constructions heretofore used a certain number of ampere turns were necessary to lift the armature the stroke 2^a , in the present construction only substantially one half of the material and energy are necessary to perform the same amount of work, considering the same magnetical proportions and temperature rise of the coil as in the old type of magnet.

In order to lessen the impact of core 11 against core 10 when core 11 travels through gap a , various means may be employed well known in this art. For instance a rod 16 preferably of non-magnetic material, may be fastened in core 11 and extend loosely centrally through core 10 into an upward extension 17 of yoke 2 and may be provided with a head 18 adapted to slide freely in the recessed portion of extension 17. This extension 17 has a cover 19 suitably fastened to it and springs 20 and 21 are disposed on either side of head 18 so that at the upward impact of core 11 against core 10, spring 20 will abut against cover 19 shortly before gap a is completely traversed and thus lessen the impact. When the magnet is deenergized and the armature drops off, spring 21 comes into effect and prevents a too abrupt dropping of the armature.

The modifications shown in Figs. 2, 3 and 4 merely represent forms which may be given to the lower portion of core 11 and to armature 3 to obtain in the end the same result, that is to say to increase the resistance of the direct path between housing 1 and core 11 after the first gap a has been traversed by the core so as to now force the lines of force from the housing 1 into armature 3. For instance in Fig. 2

the lower portion of magnet coil 5 and spool 6 is of such shape so as to form a recess 22, of suitable size to receive a collar 23 integral with core 11. Otherwise the structure may be the same as shown in Fig. 1. For instance armature 3 may be of the same shape and the total stroke of the magnet may be equal to $2a$. The armature is shown in Fig. 2 in deenergized position. In this position it will be noted that the lines of force, shown in full lines, enter from housing 1 into core 11 through collar 23 which is then nearest to housing 1 so that the least resistance is offered to the lines of force. If now core 11 is lifted the distance a as previously described, collar 23 is lifted into the position indicated in dotted lines in Fig. 2 and thus moved away from the annular surface of casing 1 at which the lines of force entered collar 23. The gap $2a$ being then reduced to a the lines of force will now find this gap a the path of least resistance and travel the path indicated in dotted lines in Fig. 2 and now attract armature 3 similar to the manner described with reference to Fig. 1. In Fig. 3 a cone-shaped collar 24 is provided on core 11 which, when the armature is in the "off" position, forms the path of least resistance for the lines of force entering from casing 1 into core 11 (shown in dotted lines in Fig. 3) and which when core 11 has traveled upward the distance equal to gap a is lifted away from casing 1 so that a considerable air gap is formed through which only few lines of force can pass, the main flux then again passing through armature 3 as indicated in dotted lines. In Fig. 4 a collar 25 is provided on core 11 which slides in a recessed portion formed in spool 6 similar to that shown at 22 in Fig. 2. Below this collar, so as to form gap $25a$ is provided an inverted cup 26 which may serve as a guide for core 11 but which is so thin as to permit the passage of only an unappreciable small number of lines of force from casing 1 to core 11 after the gap between armature 3 and flange 13 has been reduced to a . Slot $25a$ may be also omitted and cup 26 and collar 25 be made integral. Thus again the main flux will now travel from casing 1 over armature 3 into core 11 and only a few lines of force will pass through cup 26 and the large gap 27, formed between cup 26 and core 11.

In Fig. 5 I have illustrated a construction in which the total stroke of the armature is subdivided into three sub-strokes equal to gap a . For this purpose the general construction of the electromagnet is somewhat modified. 1 again represents the housing for the coil 5, and 6 the spool on which the coil is disposed. 11 is the core, to the end of which the load is attached, but the armature 3 integral with core 11 in the modifications shown in Figs. 1 to 4, is in this modifi-

cation independent of core 11. Armature 3, as will be seen from Fig. 5, is slidably disposed on core 11 with a sleeve 37 of non-magnetic material interposed between the two elements. A spring 29 seated on a collar 30 normally forces armature 3 against a collar 28 integral with core 11. Armature 3 is provided otherwise with a rim 12 cooperating with an annular flange 13 integral with housing 1, similarly as described with reference to Figs. 1 to 4. Also similar to the modification shown in Fig. 2, a collar 36 integral with core 11 is provided at such height on this core that when the armature is in the full "off" position this collar 36 forms the shortest path for the lines of force entering from housing 1 into core 11. Of course this collar 36 is not absolutely necessary and core 11 can also be of construction as shown in Fig. 1. The same applies to collar 36 of Fig. 6 to be described later on. Core 10, shown in Fig. 1 as attached to yoke 2, carries in the modification shown in Fig. 5, a head 31 provided with a rim 35 near its circumference and resting with its lower side near its periphery on spool 6 which is suitably shouldered for this purpose. Housing 1 carries a hood 32 of the shape as shown in Fig. 5 which is open in the center but which protrudes sufficiently far toward the center of the magnet so that a rim 33 is formed adapted to cooperate with rim 35 similarly to the manner in which rim 12 of armature 3 and flange 13 of housing 1 previously described, cooperate, as will be hereinafter described in detail. Hood 32 is of magnetic material. Housing 1 is also provided with an upward extending rim 38 which forms as well a central guide for hood 32 as a path for the lines of force entering from head 31 into housing 1 when the core 10 is in the position shown in Fig. 5. Spool 6 is provided with an upward extension 34 also of non-magnetic material for the same reasons for which extension 7 shown in Fig. 1, is provided. Similarly to the recess 22 shown in Fig. 2, a recess 38 is provided at the lower end of spool 6 of sufficient size to permit upward movement of collar 36 therein, the depth of this recess being equal to the total stroke $3a$ of the whole armature. In deenergized position as shown, core 11 extends sufficiently upward and core 10 sufficiently downward so that a gap equal to the distance a is formed between the ends of the two cores. Moreover armature 3 is located on core 11 in such position that a gap equal to $2a$ is formed between rim 12 and flange 13. The distance between rim 35 of head 31 and rim 33 is, in this normal position, also equal to the gap $2a$. If now the electromagnet is energized the path of least resistance for the lines of force is from core 10, head 31, housing 1, collar 36, core 11,

gap a . Thereupon core 11 is attracted and traverses gap a until it contacts with core 10. Thereby collar 36 is moved away from the cylindrical surface 40 of casing 1 at which the lines of force enter into collar 36 similarly to the manner described with reference to collar 23 in Fig. 2 so that at this point a large air gap is formed which offers a greater resistance than the air gap now existing between rim 12 and flange 13 which, the gap a between cores 10 and 11 being now closed, is now equal to a . Thus the main flux passing now through armature 3 the latter is attracted and the whole armature with core 11 moved up another step equal to the gap a . After this has happened rim 12 abuts against flange 13 and core 11 has pushed core 10 upward the distance equal to the gap a , so that thereby the cylindrical surface 45 of head 31 has been shifted upward and away from rim or extension 38 a distance equal to gap a . It has been previously stated that the flux during the attraction of core 11 by core 10, and the attraction of armature 3 by flange 13, always passes at the upper end of the magnet from head 31 over cylindrical surface 45 to rim 38 and thence downward. By shifting head 31 upward a distance equal to the space of gap a the resistance for the flux between surface 45 and rim 38 is increased to such an amount that very few lines of force will flow through this large air gap, the height of cylindrical surface 45 being rather smaller than gap a . The distance between rim 35 of head 31 and rim 33 of hood 32 being in the normal position as shown equal to $2a$, and now after head 31 has been raised as just described, being only equal to a , and a substantially closed path now existing at the lower portion of the magnet the easiest gap for the flux to traverse, is the gap between rims 35 and 33. Therefore head 31 will be attracted by rim 33 and thus move core 11 together with the load upward a further step a since core 11 is at the same time held attracted by core 10. Core 11 is free to move this step upward in spite of armature 3 abutting against flange 13 because, as previously described, armature 3 is slidingly disposed in core 11. Thus it will be seen that though the load is lifted altogether a distance equal to $3a$ still at no time the magnetic flux used for this lifting purpose is compelled to traverse an air gap larger than the gap a but that merely the location of the gap is shifted locally in the path of the flux every time the flux has lifted the armature a step equal to a and that thus the ampere turns necessary to energize the magnet need be dimensioned only to lift the armature a distance equal to gap a and not lift the armature through a gap equal to $3a$.

Fig. 6 shows a modification in which, while at no time the gap through which the

flux passes to attract the armature is larger than the distance marked a in this figure between cores 10 and 11, still the total stroke of the lifting armature of this magnet is equal to $5a$. The successive forming of gaps equal to a as the armature progresses on its stroke is obtained in the following manner: The principal form of the electromagnet as shown in Fig. 6, may be the same as for instance shown in Fig. 5. So is for instance the casing or housing 1 which contains coil 5 and spool 6 substantially of the same form. Also the recess 39 in which collar 36 of core 11 slides may be substantially of the same form the only difference being the depth of the recess which is equal to five times the gap between cores 10 and 11, while in Fig. 5 it is only three times the depth. As previously mentioned, collar 36 is not an essential part of core 11 but the latter can also be of shape shown in Figs. 1 to 4. Also in this modification armature 3 is slidingly fitted onto core 11 and normally held in the position shown in Fig. 6 by a spring 29 seated on collar 30. Moreover an auxiliary armature 50 is interposed between core 11 and armature 3. This armature 50 has substantially the shape of a disk mounted on core 11 with a thin layer of non-magnetic material 54 interposed and abutting against a collar 28 integral with core 11, disk 50 being held against collar 28 by means of a spring 55 also seated, like spring 29 on collar 30. Rim 12 of armature 3 also in this modification coöperates with a corresponding annular flange 13 of housing 1 while a rim 51 provided on auxiliary armature 50 coöperates with an annular flange 52 provided also on the underside of the housing 1 similarly to the manner in which rim 13 is arranged. In normal position when the magnet is deenergized as shown in Fig. 6 the distance between rim 12 and flange 13 is equal to $2a$ while the distance between rim 51 of armature 50 and flange 52 of housing 1 is equal to $4a$. It may be also mentioned that a non-magnetic sleeve 53 is interposed between armature 3 and auxiliary armature 50 and which may be fastened to the latter, the armature 3 being held against the rim at the upper end of this sleeve and the latter in turn against rim 51 of armature 50 by means of spring 29. Core 10 again carries at its upper end a head 31 provided near its periphery with a rim 35, the cylindrical surface 45 of head 31 coöperating magnetically with rim 38 of housing 1 in similar manner as described with reference to surface 45 and rim 38 shown in Fig. 5. The height of surface 45 in Fig. 6 is approximately equal to the length of gap a but may be rather smaller. Spool 6 is provided with a cylindrical upward extension 59 similar to the upward extension 34 shown in Fig. 5, but in Fig. 6 a shoulder 62 is provided on this

upward extension on which a magnetically conducting ring 57 is seated, but not fastened, and protrudes inwardly from shoulder 62 sufficiently to form a rim 63 which is, in normal deenergized condition of the magnet, away from rim 35 of head 31, a distance equal to $2a$. In line with ring 57 is disposed on the outside of extension 59 a rib 58 which forms part of hood 56, the latter being similar in form to the hood 32 in Fig. 5. This hood 56 is seated on a suitable flange on housing 1 and centrally guided by rim 38 previously referred to. Hood 56 extends upwardly beyond extension 59 and forms a complete cover for the magnet and at the same time a part of the path for the magnetic flux when the armature is near the completion of the full stroke as will be hereinafter described. Hood 56 is provided centrally on the inside with a boss 60 which in the deenergized condition of the magnet is away a distance equal to $4a$ from the upper surface 61 of head 31, and adapted at certain stages of the armature stroke to be described later on, to conduct the magnetic flux.

The operation of this magnet is as follows: At the moment the magnet is energized the magnetic flux takes the following path: from core 10, through head 31, surface 45, rim 38, housing 1, surface 40, collar 36, core 11, across gap a back to core 10. All other probable paths which the flux might take such as for instance from flange 13 to rim 12 of armature 3 offer too great a resistance on account of the large air gaps located in this path. Therefore the main flux passing only through gap a core 10 will attract core 11 and thus lift the whole armature the distance a . Thereby collar 36 moves upward and away from surface 40 as described with reference to Fig. 5, and rim 12 of armature 3 approaches flange 13 so that it is only now a distance equal to a from this flange. The path for the flux at collar 36 being practically interrupted by the large air gap formed at this point, the flux will now take its way across the gap between flange 13 and rim 12, the path of the flux at the upper end of the magnet remaining up to the present still the same as previously described. If now armature 3 is attracted so that rim 12 will abut against flange 13 and the whole armature thus moves upward the second step, in other words, the second fifth of the total stroke, core 11 pushes core 10 together with its head 31, upward the distance a and by removing surface 45 from rim 38 forms a large gap at this point and at the same time reduces the gap between rim 35 and ring 57 from $2a$ to a . When this has happened the flux takes the following path as the one with least resistance: from core 10, over head 31, rim 35 across the gap now equal to a , to ring

57, thence to rib 58, hood 56, housing 1, flange 13, armature 3, auxiliary armature 50, core 11 back to core 10. Thus the only air gap in this path being the gap between rim 35 and ring 57, head 31 will be attracted by ring 57 and lift the whole armature the third fifth of the total stroke since core 11 is at the same time held attracted by core 10. The whole armature can move this distance in spite of armature 3 abutting against flange 13 because this armature is, as previously mentioned slidingly disposed on sleeve 53. At this moment a complete path is formed again in the upper portion of the magnet by rim 35 abutting against ring 57 but in the lower portion of the magnet the core 11 by being lifted this third fifth has also lifted auxiliary armature 50 away from armature 3 far enough to form a gap of considerable size so as to offer a great resistance to the flux at this point. While auxiliary armature 50 has thus been removed from armature 3 it has been at the same time now moved close enough toward the bottom of housing 1 so that its rim 51 is now only away from annular flange 52 a distance equal to a . This gap between rim 51 and 52 now forms the gap of least resistance in the path of the flux so that the main flux will pass through this gap and flange 52 will attract auxiliary armature 50 which thereby raises core 11 the fourth fifth of its total stroke. Head 31 being raised this distance together with core 11 will also lift ring 57 off its seat and move it away from rib 58 so that a large gap will be thereby formed between ring 57 and rib 58 which offers great resistance to the flux. When the armature has thus been raised four fifths of the distance it will be noted that surface 61 of head 31 is now only away from boss 60 one fourth of the distance $4a$ between boss 60 and head 31, previously described, or in other words, now a gap exists between boss 60 and surface 61 only equal to a . Since auxiliary armature 50 now abuts against annular flange 52 there exists practically a closed magnetic path in the lower portion of the magnet while in the upper portion the gap of least resistance equal to a is formed between boss 60 and surface 61 so that substantially the entire flux will now pass through this gap, and boss 60, by attracting head 31, will lift the core 11 the last fifth of its total stroke. The portion of core 11 extending through auxiliary armature 50 thereby slides upward in this armature. Thus the magnet has lifted the main armature to which the load or other elements to be moved may be attached a certain distance, only one fifth of which distance forms at any time the maximum air gap through which the magnetic flux must pass in order to lift the armature. To the interrupting of the closed path for the flux

at this point such as for instance between surface 45 and rim 38 in Figs. 5 and 6 or between ring 57 and rib 58, as has been described above, no great resistance is offered by the magnetic flux because as has been previously pointed out with reference to Fig. 1 these elements move away from each other at right angles to the magnetic flux in which direction, as is well known, the least resistance is offered to the displacement of the two members of magnetic material traversed by the magnetic flux. Of course there is always a certain leakage in the interrupted position, as indicated in Figs. 3 and 4, and also a small leakage in such places, where the different parts are shouldered upon each other, as at shoulder 9, 28 etc., which produces a certain pull in opposite direction of the working pull. However, this counter action can be easily minimized and balanced by proper dimensioning the attracting surfaces and giving the magnetic parts the proper shape. This way the working pull may be rendered constant in all positions of the armature or vary in any desirable way. Moreover, as has been also clearly described, at such places where two members of magnetic material are separated always a thin layer of non-magnetic material is interposed, which, while it does not offer, owing to its thinness, a great resistance to the straight passing of the magnetic flux from one conducting element to the other, lessens the friction of the two magnetically conducting elements upon each other. Moreover these non-magnetic layers form at such places where they are disposed a small constant resistance when the flux passes through them so that in dimensioning the magnet sufficient ampere turns can be easily provided to overcome the resistance offered by these layers.

This new magnet type described herein can also be applied to alternating current magnets, the magnetic circuits then being laminated in the usual way. The saving of copper is just as great as for the D. C. magnet, and also the efficiency is increased to a considerable extent.

From the foregoing description of all the modifications it will be seen that the total stroke of the magnet armature may be subdivided into any suitable number of small gaps which may all be of substantially uniform size and which are formed to size successively as the armature progresses on its stroke. While I have shown only a limited number of subdivisions such as for instance 2, 3 and 5 as examples, and while I have shown a particular structure to suit each modification, it is obvious that such structures as shown do not constitute a limitation of my invention inasmuch as the actual magnet structure may vary considerably according to the purpose for which it is employed

and according to the number of gaps into which the total stroke of the magnet is subdivided.

What I claim is:

1. A lifting electro-magnet of the character described having the lifting stroke of its armature subdivided into a plurality of air gaps successively traversed and closed by substantially the entire magnetic flux during the lifting period, each succeeding gap being reduced to a size adapted to conduct said flux after the preceding gap is closed by the flux.

2. A lifting electro-magnet of the character described having the lifting stroke of its armature subdivided into a plurality of air gaps successively traversed and closed by the magnetic flux during the lifting period, each succeeding gap being reduced to a size to form the path of least resistance for the flux after the preceding gap is closed by the flux.

3. A lifting electro-magnet of the character described having the lifting stroke of its armature subdivided into a plurality of air gaps, said gaps being closed successively by the flux during the lifting period, each succeeding gap being reduced to the desired size to form the path of least resistance for the flux after the previous gap is closed, and means for directing the magnetic flux successively through each of said gaps.

4. A lifting electro-magnet of the character described having the lifting stroke of its armature subdivided into a plurality of air gaps, said gaps being closed by the flux successively during the lifting period, each succeeding gap being reduced to the desired size to form the path of least resistance for the flux after the previous gap is closed, and each of said gaps except the first to be closed, forming successively a shunt path for the flux, and means for interrupting the main path of the flux near said shunt path formed by the succeeding gap to direct the entire flux through said succeeding gap.

5. A lifting electro-magnet of the character described having the lifting stroke of its armature subdivided into a plurality of air gaps, said gaps being closed by the flux successively during the lifting period, each succeeding gap being reduced to the desired size to form the path of least resistance for the flux after the previous gap is closed, and each of said gaps, except the first to be closed, forming successively a shunt path for the flux, and means operated by the magnet armature when traversing the previous gap for interrupting the main path of the flux near the shunt path, formed by the succeeding gap, to direct the entire flux through said succeeding gap.

6. A lifting electro-magnet of the character described having the lifting stroke of its armature subdivided into a plurality of air

gaps, said gaps being closed by the flux successively during the lifting period, each succeeding gap being reduced to the desired size to form the path of least resistance for the
5 flux after the previous gap is closed, and each of said gaps, except the first to be closed, forming successively a shunt path for the flux, and magnetically conducting movable members normally interposed in the
10 path of the normal magnetic flux, and each of said members shunted by one of said gaps and operatively connected with the main armature, which, when traversing and closing one of said gaps, removes the conducting member of the subsequent gap from the
15 magnetic path to direct the entire magnetic flux through said subsequent gap.

HEINRICH POTH.

Witnesses:

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GEO. B. NICKEL.