Sept. 10, 1946. E. A. DERUNGS 2,407,603

ELECTROMAGNET

Filed Dec. 23, 1943 2 Sheets-Sheet 1

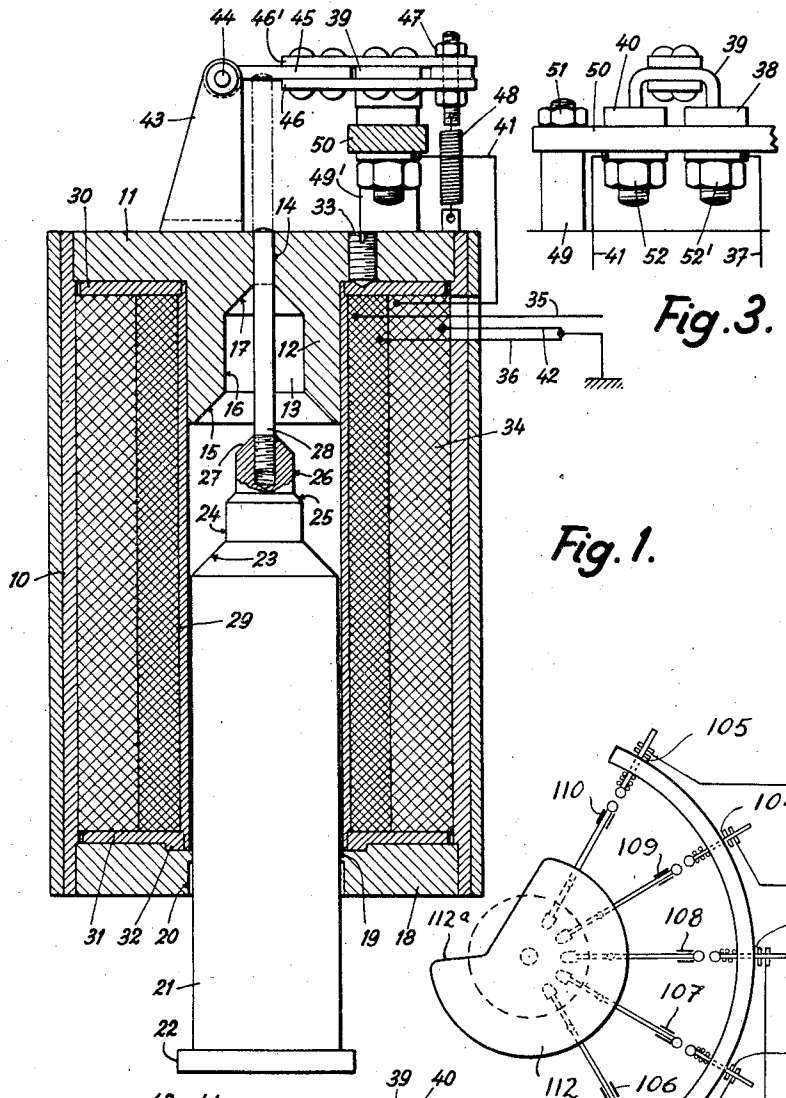


Fig. 1.

Fig. 3.

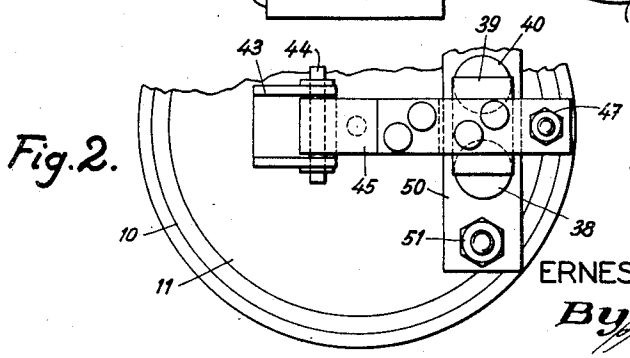


Fig. 2.

Fig. 7.

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Sept. 10, 1946. E. A. DERUNGS 2,407,603

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Filed Dec. 23, 1943 2 Sheets-Sheet 2

Fig. 6.

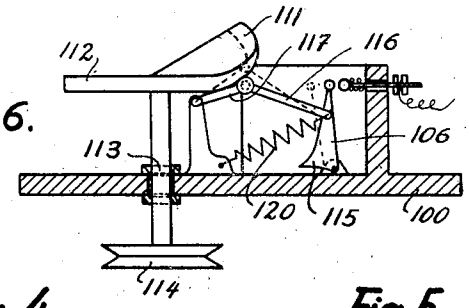


Fig. 4.

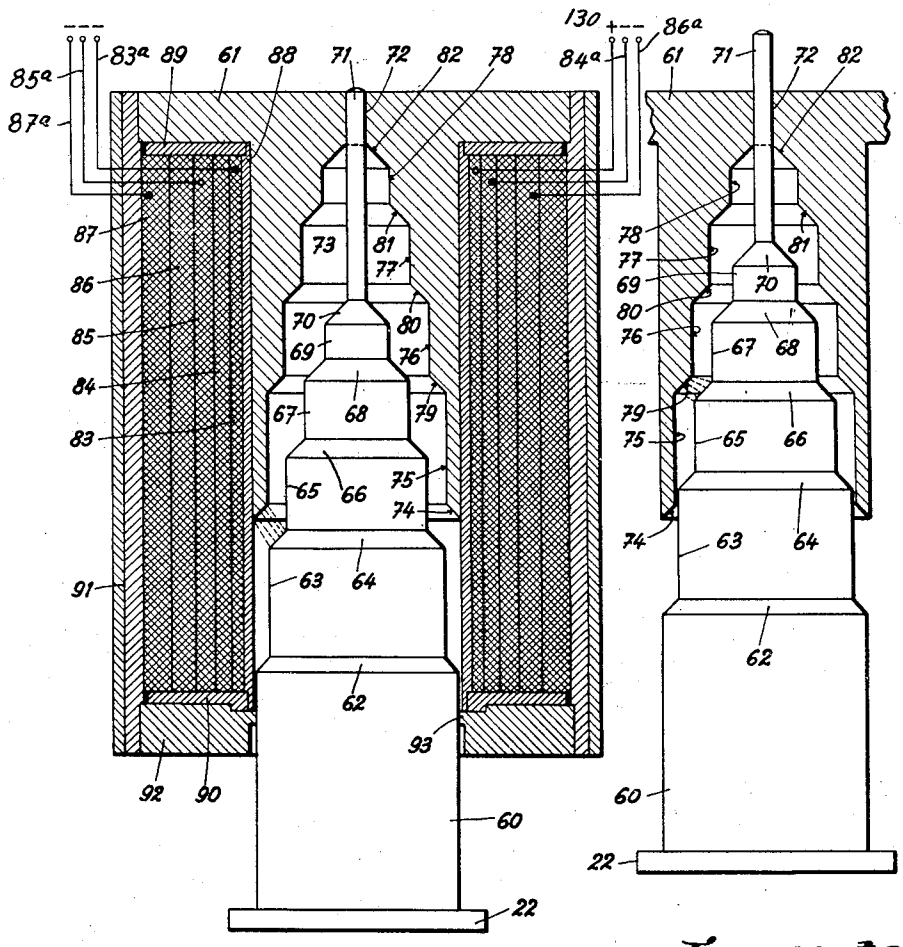


Fig. 5.

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ELECTROMAGNET

Ernest Alphonse Derungs, Le Locle, Switzerland

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1

This invention relates to an electromagnet. Electromagnets are often required to have a long stroke while the force of attraction should be as uniform as possible in order that the working conditions of the magnet approach those of a motor.

For obtaining this result, a mechanical device has hitherto often been inserted between the electromagnet and the object controlled by the same, for instance, cams for compensating the great differences in the force of attraction between the moment when the air gap is a maximum and the moment when it is a minimum. In this case, the loss of energy caused by the dispersion of the lines of force occurring at the beginning of the attraction is not recoverable. Besides this the mechanical device for obtaining a uniform force of attraction to be transmitted represents a complication diminishing the efficiency of the apparatus.

Object of the present invention is to obtain an electromagnet permitting the force of attraction to be rendered uniform without providing additional means, while constantly disposing of the required energy at a maximal efficiency.

The electromagnet according to the invention comprises two mutually movable core and armature members approaching each other when the exciting circuit is closed, the end portion of at least one of these members comprising a number of parts arranged in steps with surfaces gradually diminishing towards the end of the member, in order, during the mutual approaching of the members, to obtain a canalisation of the lines of force and, in consequence, an adjustment of the force of attraction.

In a preferred embodiment means are provided for avoiding a violent shock at the end of the armature stroke. These means are: amplifying the attraction at the beginning of the stroke of the movable armature and reducing it towards the end of the stroke.

The first of these means consists in the form given to the end portions of the members approaching each other. By preference, one of these members has a staggered end portion which corresponds to a hole of slightly greater lateral dimensions in the other member. The steps of substantially regular form can be interconnected by parts whose inclination is preferably in the order of 45 degrees. The said corresponding hole in the other member need not necessarily fit the steps exactly. The ratio between the cross sections of the end portion and of the cross section of the main body of the armature, as well as the ratio between the lengths of the different steps

2

can be chosen so that a maximal recovery of the leakage lines of the magnetic field is obtained, this, however, within limits in which the force of attraction, owing to the deflection of the lines of force in the interior of the hole, does not show a diminution which is injurious to a reliable working during the closing of the electromagnet.

The second means consists in the manner of excitation. By preference, the intensity of the exciting current is greatest at the beginning of the attraction of the movable armature and gets smaller towards the end of the stroke where the air gap is smallest. This variation in the current intensity can be obtained by well-known means, e. g. by the use of one or several change-over switches operated by the movable armature during its stroke and by separate circuits which are successively connected in parallel and in series by these change-over switches, or by the use of any resistances which are connected to the exciting circuit by means of these change-over switches.

It is understood that these two means can be used separately and that the first one alone can specially form a sufficient adjusting means for many applications.

The accompanying drawings illustrate, by way of examples, two embodiments of the electromagnet according to the invention.

Fig. 1 is an axial section of the first embodiment;

Fig. 2 is a partial plan view of the same,

Fig. 3 illustrates a detail of a switch.

Fig. 4 is an axial section of the second embodiment.

Fig. 5 shows the movable armature and the fixed core in another mutual operating position, than that in Fig. 4.

Fig. 6 is an elevation, partly in section, of a switching device controlling the excitation of the windings in the second example, and

Fig. 7 is a plan view thereof.

In Figs. 1 to 3 an electromagnet with a movable, central dipping armature is represented, which is greatly saturated and receives the exciting current from a source of current with practically constant voltage, for instance, from a storage battery.

As may be seen in Figs. 1 and 2 of the drawings, a tubular, subdivided steel body 10 of the electromagnet ends on the one side in a steel disc 11 comprising a fixed core 12 provided with a hole 13 ending in a bore 14. This hole 13 has a truncated cone portion 15 followed by a cylindric part 16 and another truncated cone portion

17. The cone angle of the portions 15 and 17, that is the angle between the generating line of these portions and the central axis of the electromagnet, is about 45°. On the other end the tubular body 10 has a steel disc 18 having a flange 19 for centering the movable armature 21 and at 20 a diameter slightly greater than that of the flange 19. The movable steel armature 21 of cylindrical form carries on its outer end a shoulder 22 and on its inner end a truncated cone surface 23 followed by two cylindrical portions 24 and 26 interconnected by another truncated cone 25, further followed by a third truncated cone 27 and a cylindrical guide rod 28 slidably arranged in the bore 14 of the disc 11. Hence, the section of the inner end portion of the armature 21 diminishes by steps. A spool made of a non-magnetic tube 29 fixed to the core 12 and of two steel plates 30 and 31 is centered in the disc 18 by the shoulder 32 of the plate 31 and held in place by the screw 33. In the annular space 34 are mounted two windings one of which, made of fine wire, receives the exciting current directly by the conductor 35, while the second one, formed by a thicker wire, receives the current by the intermediary of the conductor 37 from the contact 38, the conducting blade 39, the contact 40 and from the conductor 41 in order to be earthed by the conductor 42. A limit switch is formed by the support 43 fixed to the disc 11. This support 43 carries an axle 44 on which the support 45 can freely rotate. The latter is connected by two insulating bars 46, 46', on the one side, to the conducting blade 39, on the other side, to the adjustable holder 47 for a draw spring 48. Two columns 49 and 49' fixed to the disc 11 carry the insulating plate 50 held by the screws 51. To this insulating plate 50 the two contacts 38 and 40 are fixed, to which the conductors 37 and 41 are connected by the screws 52 and 52'. The proportion of the diameter of the cylindrical part 21 to the diameter of the portion 24 determines the degree of uniformity of attraction, and owing to the arrangement of the conical surfaces on the armature and on the fixed core most of the leakage lines lost in ordinary magnets are absorbed by the surfaces 15, 25 and 27; however, when the cylindrical part 26 is on the level of the cylindrical part 16, the closing of the lines of force between these two cylindrical parts 26 and 16 remains small enough as not to cause too great a diminution of the attraction force of the armature; this is also the case when the cylindrical surface 24 is on the level of the cylindrical surface 16. Besides, in order to augment the effects of canalisation of the lines of force, the passage section for the magnetic field in the interior of the tube 10 and in the pieces 11, 18, 30 and 31 is much greater than that in the cylindrical portion of the armature 21.

Operation:—Before the beginning of attraction, the electromagnet is in the position shown in Fig. 1, that is, the armature 21 has the greater distance from the core 12. When excitation takes place, the two windings are connected in parallel. The current passes through the conductor 37, the contact 38, the conducting blade 39, the contact 40 and the conductor 41 through the winding with the thicker wire and the earthed conductor 42, and for the winding with the thinner wire through the conductor 35 and the earthed conductor 36. As above-mentioned, the current density in the thicker wire is comparatively very great and the magnetisation of the armature 21 quickly reaches the limit of saturation. By the special form of the inner end portion of the movable armature 21 constituted by the cylindrical and conical parts 23, 24, 25, 26, 27 and 28 the path of the lines of force is shortened with regard to that which should have been effected by the lines of force in the air; this diminishes by so much the leakage flux which might occur between the cylindrical surfaces of the armature 21 and the tube 10. In proportion as the movable armature 21 approaches the fixed core 12, the penetration of the cylindrical parts 26 and 24 into the hole 13 tends to reduce the force of attraction owing to the deflection of some of the lines of force in a direction perpendicular to the stroke of the movable armature 21. In this way the attraction force is augmented at the beginning of the movement of the armature and diminished from the moment when it attains a value exceeding the prescribed effort to be exerted by the movable armature. As soon as the armature 21 is at the end of its stroke and the stop 22 is only at a small distance from the disc 18, the rod 28 lifts the support 45 which pivots around the axle 44 and, by means of the bars 46 and 46' takes along the conducting blade 39 which is thereby disconnected from the contacts 38 and 40 on which it was supported by the spring 48. Therefore, the exciting current of the winding with the thick wire passing through conductor 37, the contact 38, the conducting blade 39, the contact 40, the conductor 41 etc. is interrupted at this moment and the armature is now held in attracted position by the winding with the thin wire only, fed by the conductor 35; the winding with the thick wire being thus traversed by a current for a short time only.

Although the thin wire fed through the conductor 35 produces a relatively small excitation, the excellent utilisation of this excitation owing to the armature 21 and the core 12 being brought together, allows the armature to be sufficiently held by the thin wire winding only.

Fig. 4 illustrates an electromagnet which comprises a movable armature forming a dipping core 60 cooperating with a portion of the fixed core 61. The inner end portion of the core 60 presents several parts diminishing by steps towards the end in the following manner: a first truncated cone 62 is followed by a cylindrical portion 63, a second truncated cone 64, a cylindrical part 65, a third truncated cone 66, a cylindrical part 67, a fourth truncated cone 68, a cylindrical portion 69 and by a fifth truncated cone 70. To the end of this armature 60 a centering rod 71 is fixed, guided in a bore 72 of the fixed core 61. The rod 71 might even be attached to the fixed core 61 and enter a bore of the movable armature 60. The fixed core 61 has a hole 73 with inner steps which, on the movable armature 60 being at the end of its attraction stroke, fit the outer steps of the armature 60. The hole 73 of the fixed core 61 has thus a truncated cone 74, four cylindrical parts 75, 76, 77 and 78 interconnected by truncated cones 79, 80 and 81, while the part 78 is followed by a truncated cone 82. The surfaces of the truncated cones of the movable armature 60 and of the fixed core 61 have preferably an inclination of about 45° with regard to the axis of the electromagnet.

The length of the cylindrical parts 63, 65, 67 and 69 in axial direction gradually diminishes towards the inner end of the armature 60, and in an analogous manner, the length of the cylindrical parts of the hole 73 of the fixed core 61

diminishes from the exterior to the interior of the hole. Moreover, the difference between the cross sections of the cylindrical parts 63 and 65 of the armature 60 is smaller than the difference between the cross sections of the cylindrical parts 65 and 67 and this difference is smaller than that between the cross sections of the parts 67 and 69, so that the surfaces of the connecting truncated cones become higher towards the inner end of the armature 60, for compensating the diminution of the diameter of these surfaces.

Around the fixed core 61 and the movable armature 60 an exciting coil is arranged which is subdivided into five different windings 83, 84, 85, 86 and 87. The coil is carried by a tube 88 of non-magnetic material and two steel discs 89 and 90 and the closing of the magnetic circuit is obtained by a tubular steel member 91, an annular steel disc 92 and the fixed core 61. The disc 92 has a flange 93 which, on the excitation of the coil, is saturated by the magnetic flux and prevents a lateral adherence of the movable armature 60.

The excitation of the coil is controlled by means of a switching device which can be operated by hand or automatically in dependence on the driving moment or on the speed of a machine, or on the time, or on a combination of these means. This switching device preferably operates in such a way that one can excite at will either the first winding 83 solely, or the two windings 83 and 84, or the three windings 83, 84 and 85, the four windings 83 to 86, or all the five windings together. The switching device might also be operated by the guide rod 71. An example of a switching device is given in Figs. 6 and 7, allowing the excitation of the windings to be progressively controlled. A frame 100 carries yieldably mounted contact members 101, 102, 103, 104, and 105 connected to the outgoing lines 83*a* to 87*a* of the windings 83, 85, 84, 86 and 87. Said contact members 101 to 105 cooperate with additional contact members in the form of pivoted arms 106, 107, 108, 109 and 110 kept open by springs 120. Each of these arms is operated by rods 116 and 117 acted upon by a single cam disc possessing a helicoidal part 111 and a flat part 112. The shaft 113 of this cam disc is mounted in a bearing of the frame 100 and carries a driving means in the form of a pulley 114. When the cam disc is rotated in the anticlockwise direction, it causes progressively the closing of all contacts beginning at the winding 83 and ending at the winding 87. When the edge 112*a* of the cam disc releases the arms 106 to 110, these latter abut with their ends 115 on the frame 100 while the rods 116 and 117 take the position shown in dotted lines in Fig. 6. The arrangement shown in Figs. 6 and 7 insures both an abrupt interruption of the contact members when the cam disc releases the rods 116, 117 and a contact pressure which suffices for adequate switching. All winding lines in Fig. 4 are connected at one end to the positive pole 130 of a current source and the excitation of each winding is established as soon as the other end is connected to the negative pole by the switching device.

The rest position of the movable armature 60 is approximately that shown in Fig. 4. If, in this position, an electric current traverses the inner winding 83, a small excitation is produced and the lines of force are formed in the air gap between the inclined surfaces 74 and 64 of the core 61 and the armature 60. Since these surfaces lie relatively close together, the small excitation produced by the winding 83 suffices to attract the armature 60 until the cylindrical surfaces 63 and 75 begin to overlap each other (Fig. 5). In this case the lines of force produced by the winding 83 are deflected perpendicularly to the axis of the armature 60 and, in consequence, can no longer advance the latter. If the two windings 83 and 84 are now fed with current, the saturation of the lines of force in the portion 75 of the fixed core 61 is such that further lines of force pass through the air gap between the inclined surfaces 66 and 79 and the movable armature 60 is again attracted until the cylindrical surfaces 65 and 76 overlap each other and the lines of force are deflected anew perpendicularly to the axis. When the winding 85 is excited together with the windings 84 and 83, a similar process is repeated and so forth until the entire coil is excited and the movable armature 60 is at the end of its stroke.

From the foregoing it may be seen that by the variation of the excitation during the displacement of the armature it is possible to obtain a canalisation of the lines of force and an adjusting of the attraction force.

The movable armature can, for instance, carry out the whole stroke in an intermittent movement of any duration whatever. On exciting the five windings simultaneously the stroke is carried out in a rapid continuous movement. On exciting only the inner winding 83, or the two windings 83 and 84, or the windings 83, 84 and 85 etc., the armature 60 is displaced up to an intermediary position corresponding to the degree of excitation of the coil.

It is evident that in lieu of utilising a certain number of different windings, the variation of the excitation can be reached by a single, non-subdivided coil which is combined with a variable outer resistance progressively connected in by an independent control or by the movement of the rod 71.

The described electromagnet might be combined with a device transmitting movement by means of cams, operating as moment and speed varier, or with an absorbing device (dash-pot).

In order to fix the stops between two partial excitations exactly, the single steps of the end portions of the armature and the fixed core might have a saturation flange analogous to the guide flange 93.

The outer end of the armature 60 has a shoulder 22 destined to come into contact with the fixed disc 92 so that between the cooperating surfaces of the core 61 and the armature 60 a small air gap is possible for acting against the remanence in the fixed core and the armature. This shoulder 22 might be adjustable in order to adjust the period of remanence when the period of excitation is controlled.

What I claim is:

1. In an electromagnet, an exciting circuit, a core member, and an armature member arranged to approach each other when said exciting circuit is closed, at least one of said members having a number of relatively fixed parts arranged in steps and comprising surfaces gradually diminishing towards the end of said member, said member being disposed with regard to the other member in such a cooperating position that during the mutual approaching of said members a canalisation of the lines of force is obtained.

2. In an electromagnet, an exciting circuit, a core member, and an armature member arranged

to approach each other when said exciting circuit is closed, at least one of said members having, parts of rectangular axial section, arranged in steps, gradually diminishing towards the end of said member, and portions comprising surfaces inclined with regard to the axis of said armature member and interconnecting said parts.

3. In an electromagnet, an exciting circuit, a core member, and an armature member arranged to approach each other when said exciting circuit is closed, at least one of said members having, parts of rectangular axial section arranged in steps, gradually diminishing towards the end of said member, and portions comprising surfaces inclined by 45° with regard to the axis of said armature member and interconnecting said parts.

4. In an electromagnet, an exciting circuit, a core member, and an armature member arranged to approach each other when said exciting circuit is closed, one of said members having outer staggered surfaces gradually diminishing towards the end of said member, the other of said members comprising a hole staggered correspondingly to said staggered surfaces, said staggered surfaces and said staggered hole being disposed in such mutual cooperating position that during the mutual approaching of said members a canalisation of the lines of forces is obtained.

5. In an electromagnet, an exciting coil comprising different concentrical windings, a core member, and an armature member arranged to approach each other when one of said windings is closed, at least one of said members having a number of relatively fixed parts arranged in steps and comprising surfaces gradually diminishing towards the end of said member, said member being disposed with regard to the other member in such a cooperating position that during the mutual approaching of said members a canalisation of the lines of force is obtained.

6. In an electromagnet, an exciting circuit, a core member, and an armature member arranged to approach each other when said exciting circuit is closed, one of said members having outer staggered surfaces gradually diminishing towards the end of said member, the other of said members comprising a hole staggered correspondingly to said staggered surfaces, said staggered surfaces and said staggered hole being disposed in such mutual cooperating position that during the mutual approaching of said members, a canalisation of the lines of force is obtained, a guide on one of said members, and a rod slidably entering said guide to guarantee mutual concentricity of said members.

7. In an electromagnet, an exciting circuit, a core member, and an armature member arranged to approach each other when said exciting circuit is closed, one of said members having outer staggered surfaces gradually diminishing towards the end of said member, the other of said members comprising a hole staggered correspondingly to said staggered surfaces, said staggered surfaces and said staggered hole being disposed in such mutual cooperating position that during the mutual approaching of said members a canalisation of the lines of force is obtained, and a saturation flange on at least one of said members destined to the passage of the magnetic flux between said members.

8. In an electromagnet, an exciting circuit, a core member, an armature member arranged to approach each other when said exciting circuit is closed, one of said members having outer relatively fixed staggered surfaces gradually diminishing towards the end of said member, the other of said members comprising a hole staggered correspondingly to said staggered surfaces, said staggered surfaces and said staggered hole being disposed in such mutual cooperating position that during the mutual approaching of said members a canalisation of the lines of force is obtained, a guide on one of said members, a rod slidably entering said guide to guarantee mutual concentricity of said members, and a switch arranged to vary the exciting current and to be controlled by said rod.

9. In an electromagnet, an exciting circuit, a fixed core member, a movable armature member arranged to approach said core member when said exciting circuit is closed, at least one of said members having a number of parts arranged in relatively fixed steps and comprising surfaces gradually diminishing towards the end of said member, said armature member being disposed with regard to said core member in such a cooperating position that during the approaching of said armature member a canalisation of the lines of force is obtained, and a shoulder on said armature member destined to come into contact with said fixed core member outside of the concentration of the lines of force, for establishing an air gap acting against the remanence in said members.

10. In an electromagnet, an exciting coil comprising a number of concentrical windings, a core member, and an armature member arranged to approach each other when one of said windings is closed, at least one of said members having a number of parts corresponding to the number of said concentrical windings and arranged in steps and comprising surfaces gradually diminishing towards the end of said member, said member being disposed with regard to the other member in such a cooperating position that during the mutual approaching of said members a canalisation of the lines of force is obtained.

11. In an electromagnet, an exciting coil comprising a number of concentrical windings, a core member, an armature member arranged to approach each other when one of said windings is closed, at least one of said members having a number of parts corresponding to the number of said concentrical windings and arranged in steps and comprising surfaces gradually diminishing towards the end of said member, said member being disposed with regard to the other member in such a cooperating position that during the mutual approaching of said members a canalisation of the lines of force is obtained, and a switching device arranged to allow the inner of said concentrical windings of being at first excited and then one after the other of said concentrical windings following one another towards the outside until the entire coil is excited.

12. In an electromagnet according to claim 1, an adjustable resistance in series with said exciting circuit.

13. In an electromagnet according to claim 1, a resistance in series with said exciting circuit and adjustable by the movement of said armature member.

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