

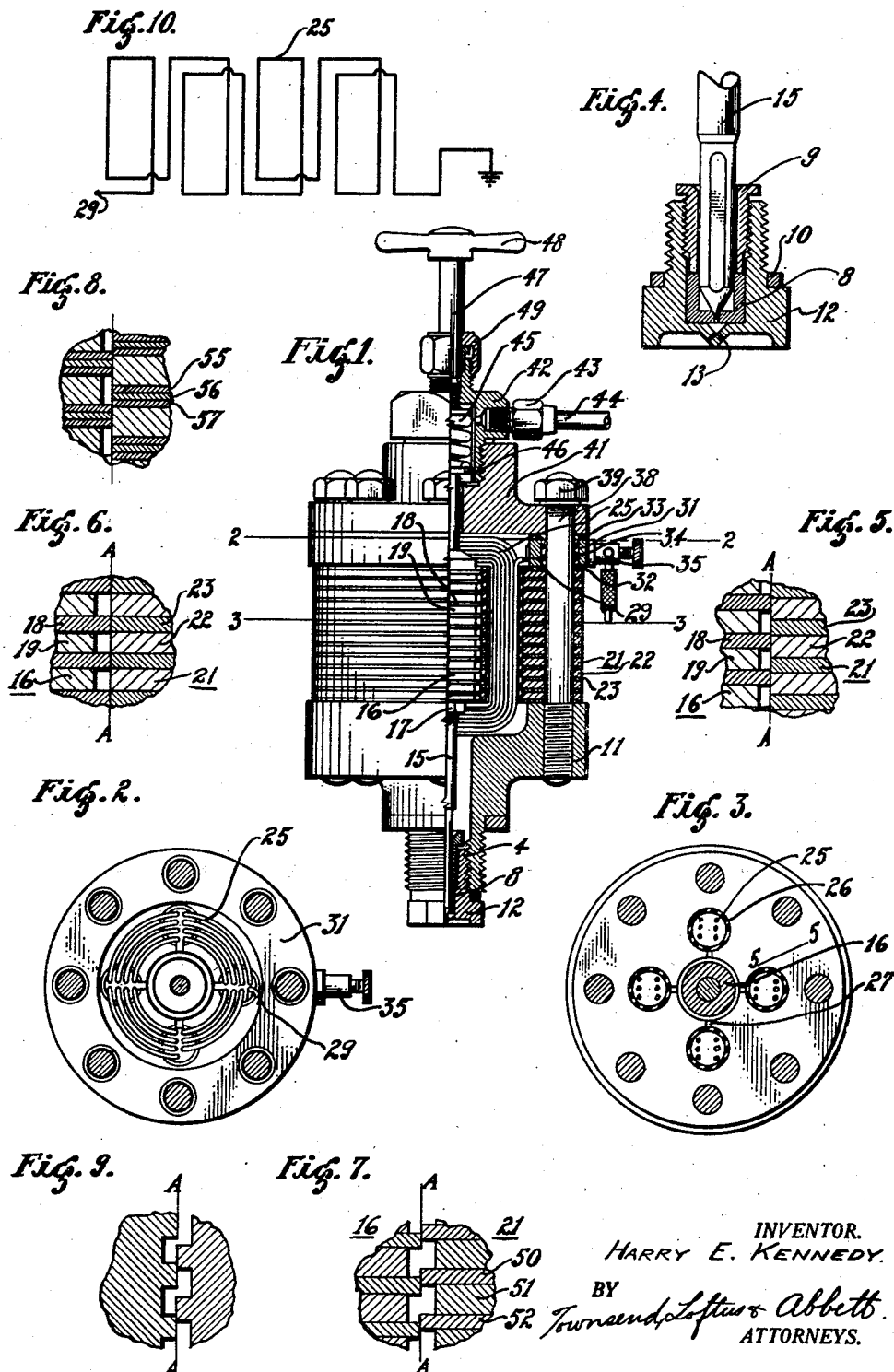
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MAGNETIC STRUCTURE

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MAGNETIC STRUCTURE

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This invention relates to magnetic structures capable of operating such devices as valves and the like having reciprocable parts. Generally speaking there are two types of electromagnets, that is, electromagnets of the solenoid and the plunger type and tractive electromagnets. It is well known, of course, that these two types have different force distance characteristics in that the tractive type exerts a continuously increasing force as its air gap diminishes until a maximum is reached when no further movement can take place. In the solenoid and plunger type when the plunger is just entering, a relatively feeble force exists which rapidly increases as the plunger continues to enter until a maximum is reached after which no change takes place until a point is reached when the force tends to diminish to zero and thereafter reverses its direction. I have found that neither of these two forms are satisfactory for certain functions such as in operating a reciprocable fuel metering valve and like devices where a relatively large initial force is necessary to overcome inertia, spring pressure and the force resulting from an unbalanced oil pressure. The main reasons for this is that it is desirable in such devices that the electromagnet utilized in operating reciprocable parts thereof be capable of exerting its maximum force at the beginning of the stroke.

It is the principal object of the present invention to provide an improved magnetic structure particularly applicable for operating such devices as reciprocable valves wherein it is essential that the electromagnet be capable of exerting its maximum force at the beginning of its operation.

This object is accomplished by constructing the stator with a pole face made up of stratified sections of varying magnetic reluctance across its active face and may be constructed of alternate strata of magnetic and non-magnetic material. A winding is provided so that alternate poles are formed around the circumference of the armature of the magnetic structure when energized. The armature which carries the reciprocable element is also provided with an outer stratified face, said face having magnetic character-

istics similar to the stator, said armature may be constructed of magnetic material alternating with non-magnetic material. It will be clear that when the armature is placed within the stationary portion of the magnetic structure in such a position that the magnetic laminae are in registry with one another, the reluctance of the magnetic circuit will be a minimum and this will be the position which the armature will assume when the winding is energized and there is no restraint on the armature. If, however, the armature be displaced in either direction by less than the thickness of the strata a restoring force will result tending to re-establish equilibrium. The force of attraction of an electromagnet for its keeper varies as the square of the number of lines of induction and directly as the area at the coacting surfaces. If we displace this armature, the flux density will increase until a point is reached where the increased reluctance of the magnetic circuit due to the diminution in area begins to diminish the total pull at which point the maximum restoring force will exist. In order to diminish the counter attraction of the adjacent strata the non-magnetic strata is preferably thicker than the magnetic strata. The total travel of the armature is determined by the thickness of the magnetic strata less the overlap as determined by adjustment. The armature acquires kinetic energy as it accelerates toward the equilibrium position, and so is capable of overshooting this position. In so doing it encounters a counter-magnetic force tending to retard it. In over-traveling this position of equilibrium the kinetic energy acquired by the armature is reconverted into electrical energy instead of appearing as heat at the impacting surface of a stop.

However, under certain conditions a stop may be used beneficially.

If laminations are utilized in constructing this electromagnetic structure for use where a fluid pressure is to be retained by said laminations, the laminations may be sealed by the insertion of fibrous material between the laminations, for example, as paper, or a soft coating of copper or lead plating, or gaskets may be used if necessary.

This structure makes it possible to construct a fluid-tight electromagnetic valve capable of exerting its maximum force at the beginning of its stroke, thereafter diminishing to zero, and re-converting the kinetic energy acquired during its travel into electrical energy. This construction is relatively immune from residual magnetic effects which make large spring pressures necessary to tractive types of electromagnets.

One form which the invention may assume is exemplified in the following description and illustrated by way of example in the accompanying drawing, in which:

Fig. 1 is a side view, partly in section, of an electromagnetically actuated valve illustrating the invention.

Fig. 2 is a plan view, partly in section, taken through section II—II in Fig. 1.

Fig. 3 is a plan view, partly in section taken through section III—III of Fig. 1.

Fig. 4 is an enlarged sectional side view of a fuel nozzle and its associated parts which may be employed with the invention.

Fig. 5 is an enlarged sectional view taken through section V—V of Fig. 3.

Fig. 6 is a similar view with the armature moved to its raised position.

Fig. 7 is a similar view of an alternative construction which may be employed utilizing all magnetic laminations and a stepped pole face.

Fig. 8 is a similar view of another construction utilizing multiple laminations per magnetic pole strata.

Fig. 9 is a similar view of a still further construction utilizing a non-laminated magnet structure with a stepped pole face.

Fig. 10 diagrammatically illustrates a wiring diagram which may be employed in this invention.

Referring to the accompanying drawing in Fig. 1, I have illustrated an electro-magnetically actuated fuel injection valve as one form which my invention may assume, in which a lower base 11 carries a valve nozzle 12, suitably attached thereto. However in some instances it may be advantageous to retain the nozzle in a fixed position by clamping it with a suitable retainer in any well known manner in order that the orifices 13 may assume any predetermined position relative to base 11. A removable hardened valve seat 10 may be employed for the benefit of alignment or to utilize a different material. This seat 10 is held in place by a valve guide 9 which preferably forms a very close running fit on the valve stem 15 to assure positive alignment with the valve seat. A collar or shim 8 extending between the nozzle and the base 11 may be replaced by others of varying thicknesses in order to accomplish an adjustment and thereby determine the lowermost position the armature will assume. A spring 45

acts against the end 46 of the valve stem 15, and is operatively associated with the spring adjusting rod 47, which is provided with a handle 48 for manual adjustment, and is sealed from leakage by the stuffing box assembly 49. From the foregoing it will be obvious that the normal position of the armature is determined by the adjusting washer 8 which is preferably so adjusted as to place the armature in a position of maximum pull relative to the stator as illustrated in Fig. 5.

A valve 15 is rigidly attached to a laminated armature 16 which is retained in place by the nut 17 thereon. An electromagnetic structure 21 is preferably composed of laminations such as 22 and 23 of alternately magnetic and non-magnetic material, and displaced in axial alignment with the magnetic laminations 19 of said armature. The non-magnetic laminations 19 should be preferably of some material of low specific gravity such as aluminum in order to reduce inertia.

A winding 25 is disposed through holes 26 in the laminations and wound so that it forms four alternate poles around the circumference of the armature when energized. This winding is similar to a multipolar field winding of a single phase induction motor. A slot 27 is provided between the hole 26 and the armature 16 in order that the magnetic flux will not have an iron path across the inner edge of the hole 26.

A ring 31 is insulated from the laminations by an insulating washer 32 at its lower side, a washer 33 at the upper side and bushings 34 between said ring and the thru studs 38. One end 29, of the winding 25, is firmly attached to the insulated ring 31 which carries a suitable binding post 35 thereon for attaching the actuating current supply. The other end of the coil is firmly grounded to the frame. The upper body 41, carries a spring housing 42, rigidly attached thereto, through which the fluid may be introduced as by the connection 43 and the fluid supply line 44. The studs 38 by means of the nuts 39, retain the upper body 41 in a fixed relation to the valve base 11, and firmly clamp the intermediate laminations, insulations and rings so as to prevent the leakage of the fluid from the interior thereof when under pressure.

The spring pressure may be adjusted by means of turning handle 48 through the medium of the screw threads to thereby equalize the operation of the various valves on a multicylinder motor, after having adjusted the valve seats to retain the armatures in substantially the same lower positions.

In Fig. 5 I have illustrated the approximate relative positions of the armature lamination 16 relative to the magnet laminations 21 in which the magnetic layers 18 and 23 are laterally displaced for maximum magnetic pull.

In Fig. 6 I have illustrated the laminations in axial alignment which would correspond to the position they would assume providing there was no exterior force acting on the armature to displace it when the magnet was energized.

In Fig. 7 I have illustrated an alternative type of construction which may be incorporated in the armature and/or magnet in which they are composed of all magnetic laminations, but with the alternate laminations stepped back from the pole face. (A pole face as herein employed throughout this application means a face similar to section A—A of the various views.) In this construction it is preferable to employ a thicker stepper back lamination 51 relative to the pole lamination 50 to prevent an excessive flux leakage from the lower lamination 52 to the armature lamination 53 when in the lowermost position.

In Fig. 8 I have illustrated a similar construction whereby each effective magnetic strata may be composed of multiple laminations of magnetic material wherein laminations 55, 56 and 57 constitute the magnetic pole face strata, the intermediate strata being composed of either the stepped back or non-magnetic construction.

In Fig. 9 I have illustrated a construction wherein the magnet and/or armature may be composed of a non-laminated material constructed with a stepped pole face preferably consisting of wider gaps than the magnetic pole strata.

In Fig. 10 I have illustrated a diagram of the wiring which may be employed in winding the magnetic structure to alternately oppositely polarize the electromagnet about its armature. While this is shown as a single phase winding, it is obvious that a multiple phase winding may be employed and that the winding may be incorporated with either the magnet or the armature as production and construction may best decree. A current from any suitable operating circuit may be supplied to said winding to accomplish the results required. It is further to be understood that said winding is not limited to four poles, but may consist of any even number of poles.

It is obvious that I have provided a magnetically actuated structure wherein the pull is greatest at the initial point of movement and wherein the air gap remains substantially constant during operation and may be reduced to the minimum. In fact, I recommend a very close running fit between the armature and the magnet and by utilizing the non-magnetic laminations on at least one of these units, a smooth surface will be provided to prevent the necessity of additional bearings.

While I have illustrated and described this invention as actuating a fluid metering valve

it is obvious that the magnetic structure disclosed is applicable to a multiplicity of uses such as an electro-magnetic actuated hammer and to various other uses operated electro-magnetically.

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

1. In an electromagnetic structure, a stator, an armature associated therewith and movable in an axial path, the coacting pole faces of the armature and stator being formed with complementary magnetic and non-magnetic regions alternately arranged axially of the path of movement of the armature to create alternate areas of high and low flux density.

2. In an electromagnetic structure, a stator, an armature associated therewith and movable in an axial path, the coacting pole faces of the armature and stator being formed of complementary stratifications of magnetic and non-magnetic material, the stratifications being disposed transversely to the path of movement of the armature to create alternate areas of high and low flux density.

3. In an electromagnetic structure, a stator, an armature associated therewith and movable in an axial path, the coacting pole faces of the armature and stator being formed with complementary areas of magnetic and non-magnetic metallic surfaces arranged alternately and axially of the path of movement of the armature to create alternate areas of high and low flux density.

4. In an electromagnetic structure, a stator, an armature associated therewith and movable in an axial direction, the coacting pole faces of the armature and stator being formed of spaced areas of magnetic material, said areas being spaced axially of the path of movement of the armature to create alternate areas of high and low flux density, the armature when not energized being positioned with its magnetic areas out of exact register with the magnetic areas of the stator and when energized said areas tending to come into substantial register.

5. In an electromagnetic structure, a stator including spaced magnetic laminations, an armature associated with the stator and composed of spaced magnetic laminations complementary to the laminations of the stator, the single laminations of the stator being oppositely polarized about the armature, the laminations of the armature and stator forming spaced magnetic paths of high flux density in planes perpendicular to the path of movement of the armature.

6. In an electromagnetic structure, a stator including alternately arranged magnetic and non-magnetic laminations secured together, an armature associated with the stator for movement in a path at right angles to the plane of the laminations, said armature be-

ing formed with alternate laminations of magnetic and non-magnetic material complementary to the laminations of the stator, the armature when not energized being arranged with its magnetic laminations out of exact register with the magnetic laminations of the stator and when energized the said magnetic laminations tending to come into substantial register and thereby impart movement to the armature.

7. An electromagnetic structure including a stator and an armature movable in an axial path, the pole face of the stator and armature creating a multiplicity of magnetic paths between said armature and said stator, said paths being stratified and in planes at right angles to the path of movement of the armature and being of alternately high and low reluctance.

8. In an electromagnetic structure, a stator including a series of laminations having a chamber formed therein for the reception of an armature, an armature arranged in said chamber for coaxial movement therein, the pole faces of said armature and laminations being formed to create a series of magnetic paths transversely of the path of movement of the armature and of different reluctance.

9. In an electromagnetic structure, a stator having an opening formed therethrough, an armature arranged in said opening for axial movement therein, the coacting pole faces of said stator and armature being such as to create stratified magnetic paths of different reluctance at right angles to the path of movement of the armature.

10. In an electromagnetic structure, a stator, an armature associated therewith and movable in an axial path, the coacting pole faces of the armature and stator being formed with complementary magnetic and non-magnetic regions alternately arranged axially of the path of movement of the armature to create alternate areas of high and low flux density, means determining the relative positions of the magnetic regions of the armature and stator when the former is de-energized.

11. In an electromagnetic structure, a stator, an armature associated therewith and movable in an axial path, the coacting pole faces of the armature and stator being formed with complementary magnetic and non-magnetic regions alternately arranged axially of the path of movement of the armature to create alternate areas of high and low flux density, means determining the relative positions of the magnetic regions of the armature and stator when the former is de-energized, and other means limiting the movement of the armature from de-energized position.

12. In an electromagnetic structure, a stator including alternately arranged magnetic and non-magnetic laminations secured together, an armature associated with the stator for movement in a path at right angles

to the plane of the laminations, said armature being formed with alternate laminations of magnetic and non-magnetic material complementary to the lamination of the stator, the armature when not energized being arranged with its magnetic laminations out of exact register with the magnetic laminations of the stator and when energized the said magnetic laminations tending to come into substantial register and thereby impart movement to the armature, and means determining the relative position of the magnetic laminations of the armature and stator when the former is de-energized.

13. In an electromagnetic structure, a stator, an armature associated therewith and movable in an axial path, the coacting pole faces of the armature and stator being formed with complementary magnetic and non-magnetic regions alternately arranged axially of the path of movement of the armature to create alternate areas of high and low flux density, and yielding means constantly urging said armature to de-energized position with the magnetic regions of the armature and stator in a definite relative position.

14. In an electromagnetic structure, a stator, an armature associated therewith and movable in an axial path, the coacting pole faces of the armature and stator being formed with complementary stratifications of magnetic and non-magnetic material, the stratifications being disposed transversely to the path of movement of the armature and the thickness of the non-magnetic strata being greater than that of the magnetic strata, said stratifications creating alternate areas of high and low flux density.

15. In an electromagnetic structure, a stator, an armature associated therewith and movable in an axial path, the coacting pole faces of the armature and stator being formed with complementary magnetic and non-magnetic regions alternately arranged axially of the path of movement of the armature to create alternate areas of high and low flux density, the axial dimension of the non-magnetic regions being greater than the similar dimension of the magnetic regions.

16. As an article of manufacture, a stator for an electromagnetic structure, said stator including a plurality of laminations of geometrical configuration secured together to form a unitary fluid-tight structure, said laminations being formed with complementary openings to form a chamber extending centrally through the structure for the reception of an armature, said structure being formed with recesses disposed intermediate the central opening and the peripheral surface of the structure for the reception of a winding, the said laminations being imperforate between said recesses receiving the winding and the peripheral surface of the structure, and imperforate caps forming a

part of the said structure and disposed at the opposite ends thereof to enclose the winding and an armature disposed in said central opening.

5 17. An electromagnet, an associated armature, said electromagnet being laminated, a fluid conducting path extending through said laminations, said path exposing a portion of said laminations to said fluid pressure, other portions of said laminations being
10 exposed to atmospheric pressure.

18. An electromagnet including laminations, a winding for said electromagnet, an armature associated with said electromagnet,
15 a housing for one end of said electromagnet including a valve seat, a housing for the opposite end of said electromagnet, an inlet passage to one of said housings, said housings and said laminations forming a fluid-tight conductor for fluid from said opening
20 to said valve seat.

19. An electromagnet, a winding for said electromagnet, a fluid-tight inclosure inclosing said winding, said inclosure including a
25 cover for said electromagnet, an insulated member adapted to be clamped to said cover, said insulated member being connected with one end of said winding, said cover being capable of complete removal from said insulated member while said insulated member is
30 connected to said winding, a portion of said insulated member extending outside of said fluid-tight inclosure.

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