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[54] **ELECTROMAGNET**

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[51] **Int. Cl.**...**H01f 7/08**

[58] **Field of Search**.......................335/258, 262, 279

[56] **References Cited**

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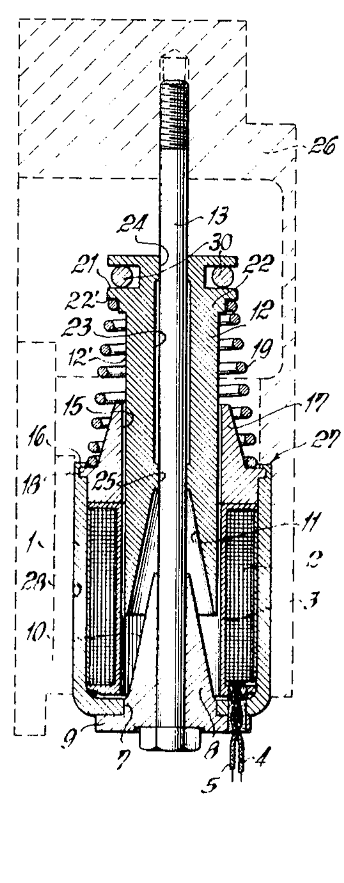
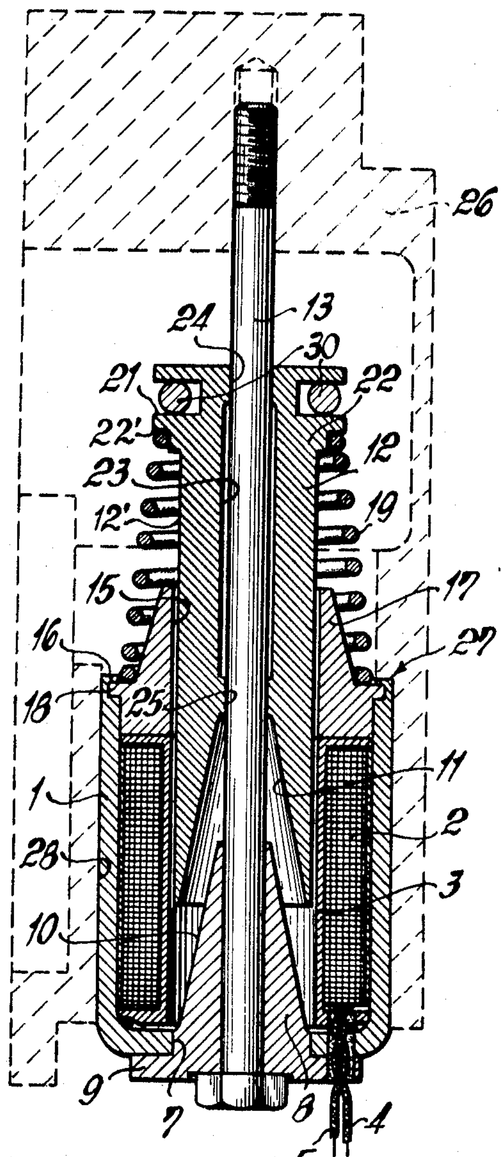
[57] **ABSTRACT**

An electromagnet has a pot-shaped enclosure having a cylindrical portion and consisting of magnetizable material, and an elongated guide means which consists of non-magnetizable material and extends substantially centrally of the pot-shaped enclosure. A winding is mounted in the enclosure. An armature is slidably mounted for movement lengthwise on the guide means in response to changes in condition of energization of the winding. The enclosure has a pole piece which defines an internal surface and the armature has an external surface defining, with said internal surface, a clearance whose width remains substantially unchanged while the armature moves with reference to the guide means. The enclosure and armature have conical pole faces which define a conical gap which varies in response to movement of the armature with reference to the guide means.

10 Claims, 1 Drawing Figure

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ELECTROMAGNET

BACKGROUND OF THE INVENTION

The present invention relates to electromagnets, and particularly to heavy-duty electromagnets capable of exerting a large force while consuming relatively little power.

Heavy-duty electromagnets which are designed to realize large lifting forces without consuming too much power are already known. These known electromagnets seek to convert most of the electrical energy directly into mechanical energy. Since the movable member of an electromagnet, or the armature, at least partially passes through the housing or enclosure of the electromagnet, which includes the coil, it is important that any frictional forces which may come about by the interaction of the armature and the stationary portions of the electromagnet be eliminated or at least minimized.

In the prior-art electromagnets, it has been attempted to remove the frictional forces by providing a guide member along which the armature is slidably mounted to thereby maintain the coaxial relationship between the armature and the electromagnet housing. In particular, the prior-art electromagnets have utilized a guide member which is centrally positioned with respect to the armature housing, and bearings have been evenly distributed over the guide means. Racers for the bearings are provided in the axial direction of the guide means thereby to ensure that the armature is guided along the guide means with insignificant generation of frictional forces. With such movement, the armature is maintained concentrically or coaxially with said armature housing and no frictional forces arise between the stationary armature housing and the moving armature.

However, the prior-art electromagnets of this type have had disadvantages. Thus, the use of bearings to remove frictional forces has been costly both in money and effort. Additionally, extra measures had to be taken to keep contaminants from being deposited in the raceways or tracks for the bearings, since this would hinder the proper operation of the armature. Also, with the arrangement just described, it has been necessary to provide close tolerances over the entire length of the armature and guide means. The precautionary measures above described were applicable over the entire interacting lengths of the armature and the guide means.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an electromagnet which overcomes the above-described disadvantages of the prior-art electromagnets.

Another object of the present invention is to provide an electromagnet which can realize large lifting forces while consuming relatively little power, and which is simple in construction and inexpensive to produce.

It is a further object of the present invention to provide an electromagnet whose armature is movable at least partially within the housing containing a cylindrical pole piece, and forming a cylindrical air gap therewith which is relatively independent of the axial displacement of the armature, and which is simple in construction and requires very little precision machining.

According to the present invention, an electromagnet comprises a hollow enclosure consisting of magnetizable material and elongated guide means at least a portion of which consists of non-magnetizable material and extends substantially centrally of said enclosure. A winding is mounted in said enclosure. An armature is slidably mounted on said non-magnetizable portion for movement lengthwise of said guide means in response to changes in condition of energization of said winding. The enclosure has an internal surface and the armature has an external surface defining with said internal surface a clearance whose width remains substantially unchanged while said armature moves with reference to said guide means.

According to a presently preferred embodiment, the guide means has an outer diameter. The armature has at least one portion which has an inner diameter which is greater than said outer diameter of the guide thereby to establish a predetermined clearance between the guide means and said first portion. The armature also has at least one second portion which has an inner diameter which is substantially equal to the outer diameter of the guide means thereby to establish slidable contact of said armature on said guide means of said second portion.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The single FIGURE is a front elevational view of an armature, shown in cross-section, according to the present invention, which also shows the armature mounted in a housing.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the drawing an armature is illustrated including a substantially hollow enclosure **1** having a cylindrical portion which consists of magnetic material. Suitable for the hollow enclosure **1** is a pot-shaped magnet as shown. A winding **2** is provided which has the connecting leads **4** and **5**. The winding **2** is wound on a spool or bobbin **3** in a conventional manner. The enclosure **1** is provided with a central opening **7** which is coaxial with the cylindrical portion of the enclosure **1**. A yoke piece **8** is provided with the wide flange **9** whose dimensions are generally greater than those of the center opening **7**, while at least a portion of the tapered yoke **8** just above the region of the wide flange **9** has a dimension which is substantially equal to the dimension of the central opening **7**. In this manner, the tapered yoke piece **8** is insertable into the interior of the hollow enclosure, as shown in the FIGURE, until the flange **9** abuts against the end wall of the hollow enclosure **1**. By appropriately selecting the dimensions of the tapered yoke piece **8**, good magnetic continuity in the magnetic circuit of the armature in the region of the yoke piece **8** and the enclosure **1**, can be maintained. The tapered yoke piece **8** is provided with a conical surface **10** which acts as a conical pole face, as will be hereinafter described.

An armature **12** is shown to be generally an elongated member and having at one end a conical surface **11** which corresponds to the conical surface **10** of the tapered yoke piece **8**. The conical surfaces **10** and **11** define between them a conical air gap whose dimension changes with sliding movement of the armature **12**. The armature **12** is generally annularly shaped and has an outside diameter **12'**.

A guide means **13**, which consists of an externally threaded portion, and here shown to be a machine bolt, passes both through the tapered yoke piece **8** as well as the armature **12**. The head of the bolt **13** abuts against the lower surface of the tapered yoke piece **8** for securing the armature to a housing as will be later described. The bolt **13** is generally provided with a smooth machine finish. The bolt **13** is made of a non-magnetizable material which does not influence magnetic fields. It is possible, however, that only a portion of the bolt **31** be made from a non-magnetizable material. Particularly, it is only necessary for the purpose of carrying out the invention that the portion of the bolt **13** which is coextensive with the conical air gap defined by the surfaces **10** and **11** be made from a non-magnetizable material. The air gap dimension which determines the size or length of the non-magnetizable portion corresponds to the position of the armature **12** in its outermost extended position in the upward direction. Stated another way, it is not necessary that the portions of the bolt **13** which are always within the confines of either the yoke **8** or that portion of the armature **12** above the conical surface **11** to be made from non-magnitizable material.

The annular pole-piece **17** is provided with the flanged portion **18** which mates with the beaded edge **16** of the enclosure **1**. The lower surface of the pole-piece **17** abuts against the upper portion of the winding **2** to thereby secure the winding **2** within the closure **1**. The pole-piece **17** has an inner diameter which defines an internal surface **15** which is generally coextensive with the internal surface of the winding **2** so as to provide a relatively uniform cylindrical space within the closure **1** for the vertical movement of the armature **12** along the guide means **13**. The internal surface **15** of the annular pole-piece **17** and the external surface **12'** of the armature **12** together define a clearance which remains substantially unchanged while the armature **12** moves with reference to the guide means **13**.

The armature **12** is provided at the end opposite to the end bearing the conical surface **11** with a carrying portion **22**. As shown in the drawing, this carrying portion **22** is provided with an annular slot and a shoulder **22'**. Between this shoulder **22'** and the flanged portion **18**, biasing means **19**, here shown to be a conical compression spring, is inserted. The carrying portion **22** will be further described hereinafter.

The armature **12** is shown to have a first portion **23** whose internal diameter is selected to be greater than the diameter of the guide means **13**, thereby to establish a predetermined clearance between the guide means **13** and the portion **23**. The armature **12** is also shown to have two second portions **24** and **25** on each side of first portion **23**. Each portion **24** and **25** has an inner diameter which is substantially equal to the outer diameter of the guide means **13**, thereby to establish slidable contact of the armature **12** on the guide means at said second portions. According to the construction just described, close tolerances must only be provided in the regions of contacts **24** and **25**, the actual diameter of surface **23** not being very critical. Also, with the present construction the clearance between surface **23** and the guide means **13** is inherently shielded from external contaminants by the action of the contacts **24** and **25**. In this way, the length of the armature **12** coextensive with the surface **23** offers no frictional resistance to the movement of said armature **12**. The only frictional forces tending to impede the free movement of the armature **12** are those forces which are set up by the slidable contact movement of the armature **12** at the contacts **24** and **25**. If the inner surfaces of contacts **24** and **25** are smoothly finished as should be the guide means **13**, the frictional forces encountered therebetween are very small. These residual frictional forces can further be reduced by applying a minimal amount of lubrication to the guide means **13**, such as light machine oil.

In operation, the armature **12** of the electromagnet is urged by the compression spring **19** into an uppermost position, or an extended position outside the armature housing. When electrical energy is supplied to the winding **2** through the leads **4** and **5**, a magnetic field will become established in air-gap of the armature **2**. The air-gap is defined by the inner surface **15** of pole-piece **17** and the outer surface **12'** of the armature **12**. The secondary gap, described above is defined by the two conical surfaces **10** and **11** of the tapered yoke piece **8** and armature **12**, respectively. The establishment of the electromagnet fields between the two aforementioned air-gaps will have the tendency to urge the armature **12** into a retracted position within the armature housing. This action of the electromagents is well known and will not be further described here. It should be noted, however, that the downward axial movement of the armature **12** has two effects. The first effect is to decrease the gap defined by the surfaces **10** and **11**, and the second is to compress the compression spring **19**. However, it should be noted that the air-gap between the outer surface **12'** of the armature **12** and the internal surface **15** of pole-piece **17** remains substantially constant for all axial positions of the armature **12**. As a result, no frictional forces arise between the external surface **12'** and any internal dimension of either the pole-piece **17** or of the spool **3**.

An electromagnet as described above, has many potential applications. For example, the electromagnet in the FIGURE will be described as being utilized as the fuel injection pump of a combustion engine. Thus, case **26** forms part of the fuel injection pump. The case **26** has a shoulder **27** which is adapted for abutment with the flanged edge **16** of the enclosure **1**. The guide means **13**, a bolt in this embodiment, is meshed at the top end with the case **26**. The bolt **13** is advanced in the direction of case **26** until the head of the bolt forcefully abuts on the flange **9** of the tapered yoke piece **8**.

In the process, a good contact is assured between the tapered yoke piece **8** and the hollow enclosure **1** so as to provide minimum reluctance in the magnetic circuit. The purpose of the end section or carrying portion **22** is merely to engage with a member whose movement it is designed to control with the electromagnet. Accordingly, the actual configuration of carrying portion **22** is not critical and any configuration which will carry or urge such member to move with the armature is satisfactory. Shown in the FIGURE, the carrying portion **22** is shown to comprise an opening, here an annular slot, which is suitable for mating with a number of complementary configurations. One such configuration is a forked-end of a lever, which forms part of a fuel injection pump of a combustion engine. The forked end comprises of two prongs **30**, shown in cross-section in the FIGURE. In this manner, whenever excitation is supplied to winding **2**, the armature **12** will urge the prongs, and therefore the lever, to move in a downward direction. When the excitation is removed, the compression spring **19** urges the armature **12** back to its normal position and the prongs **30** likewise follow.

Although the electromagnet is shown in the FIGURE to include a compression spring **19**, the use of such a spring does not form a critical part of the invention. Likewise, the use of the conical air-gap defined by the surfaces **10** and **11** need not necessarily be utilized. Any other configuration of airgaps between the lower end of the armature **12** and the enclosure **1** would be equally suitable.

The composition of the closure **1** is likewise not critical to the present invention, materials used for this purpose being well known in the art.

While the invention has been illustrated and described as embodied in an electromagnet forming part of a fuel injection pump of a combustion engine, it is not intended to be limited to the details shown, since various modification and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims:

1. In an electromagnet, a combination comprising a hollow enclosure in the shape of a pot-shaped magnet and consisting of magnetizable material; elongated guide means at least a portion which consists of non-magnetizable material and extends substantially centrally of said enclosure; a winding mounted in said enclosure; and an armature slidably mounted on said portion for movement lengthwise of said guide means in response to changes in condition of energization of said winding, said enclosure and said armature having conical pole faces which define a conical gap which varies in response to movement of said armature with reference to said guide means.

2. In an electromagnet, a combination comprising a hollow enclosure consisting of magnetizable material; elongated guide means at least a portion of which consists of non-magnetizable material, extends substantially centrally of said enclosure and has a predetermined outer diameter; a winding mounted in said enclosure; and an armature slidably mounted on said portion for movement lengthwise of said guide means in response to changes in condition of energization of said winding, said armature having at least one first portion having an inner diameter which is greater than said outer diameter of said guide means thereby to establish a predetermined clearance between said guide means and said first portion, and said armature having at least one second portion having an inner diameter which is substantially equal to said outer diameter thereby to establish slidable contact of said armature and said guide means along said second portion.

3. A combination as defined in claim **2**, wherein said enclosure is a pot-shaped magnet having a cylindrical portion which is coaxial with said guide means; and further comprising an annular pole-piece mounted at the open end of said enclosure and having an inner diameter which defines said internal surface of said enclosure.

4. A combination as defined in claim **2**, wherein said armature has a first portion which is positioned intermediate to two second portions.

5. A combination as defined in claim **1**, further comprising biasing means for urging said armature into a normally extended position at least partially outside of said enclosure.

6. A combination as defined in claim **5**, wherein said armature has a first shoulder and said enclosure has a second shoulder, said biasing means comprising a compression spring mounted between said first and second shoulders.

7. A combination as defined in claim **1**, further comprising a housing, and wherein said guide means comprises an externally threaded portion meshing with said housing for affixing said enclosure to the latter.

8. A combination as defined in claim **1**, further comprising a movable member, and wherein said armature has at one end a carrying portion having securing means for securing said movable member, whereby said movable member shares the movements of said armature in response to energization of said winding.

9. A combination as defined in claim **8**, wherein said securing means comprises a opening having a first configuration and wherein said movable member comprises a section of a lever, such as that forming part of a fuel injection pump of a combustion engine, at least a portion of said lever section having a second configuration which is adapted to be mated with said carrying portion for being carried thereby.

10. A combination as defined in claim **9**, wherein said first configuration comprises an annular slot and wherein said second configuration comprises a forked end.

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