United States Patent [19]

Ludwig et al.

[11] **3,786,383**

[45] **Jan. 15, 1974**

[54] **PERMANENT MAGNET SOLENOID DEVICE**

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[22] Filed: **Oct. 27, 1972**

[21] Appl. No.: **301,315**

[52] **U.S. Cl.** **335/231,** 335/222

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

[58] **Field of Search** 335/222, 223, 231

[56] **References Cited**

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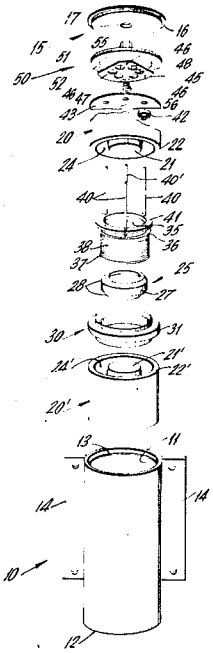
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[57] **ABSTRACT**

A pair of substantially identical high powered cylindrical magnets are arranged in axially aligned opposing relation in a cylindrical casing of non-magnetic material, with their facing ends spaced axially from each other. Each permanent magnet has a central cylindrical pole of one polarity, an annular pole of the opposite polarity and a base interconnecting its poles at the end remote from the other permanent magnet and forming the base of an open annular groove separating its two poles. An inner circular pole piece is interposed between the facing ends of the two cylindrical poles, and an outer annular pole piece is interposed between the facing ends of the annular poles, the two pole pieces defining an annular air gap having a very small radial dimension. A cylindrical winding form, of non-magnetic material and carrying a winding, is movably positioned substantially symmetrically in the air gap. A plurality, such as three, of angularly spaced pins of non-magnetic metal are connected to the winding form and extend outwardly through the annular groove of one permanent magnet and through dielectric bushings in the apertures in the base thereof. A fourth pin, constituting an electric conductor, terminates short of the winding form and is electrically connected at its inner end to one terminal of the winding and extends outwardly through a bushing in the base of the one permanent magnet for connection to a terminal of a source of electric potential. All of the pins, except the fourth pin, have their outer ends secured to a thin brass plate which is secured to a central pin or operator in turn secured centrally to a flexible diaphragm and projecting outwardly through an opening in the casing of the device. The fourth pin extends through the brass plate, with clearance. The air gap has a dimension of from 0.010 to 0.020 inches and, when the winding is energized, the operator will move 8 ounces through 0.1 inch with 6 millijoules of energy. The device is used as a trigger for missiles.

10 Claims, 4 Drawing Figures



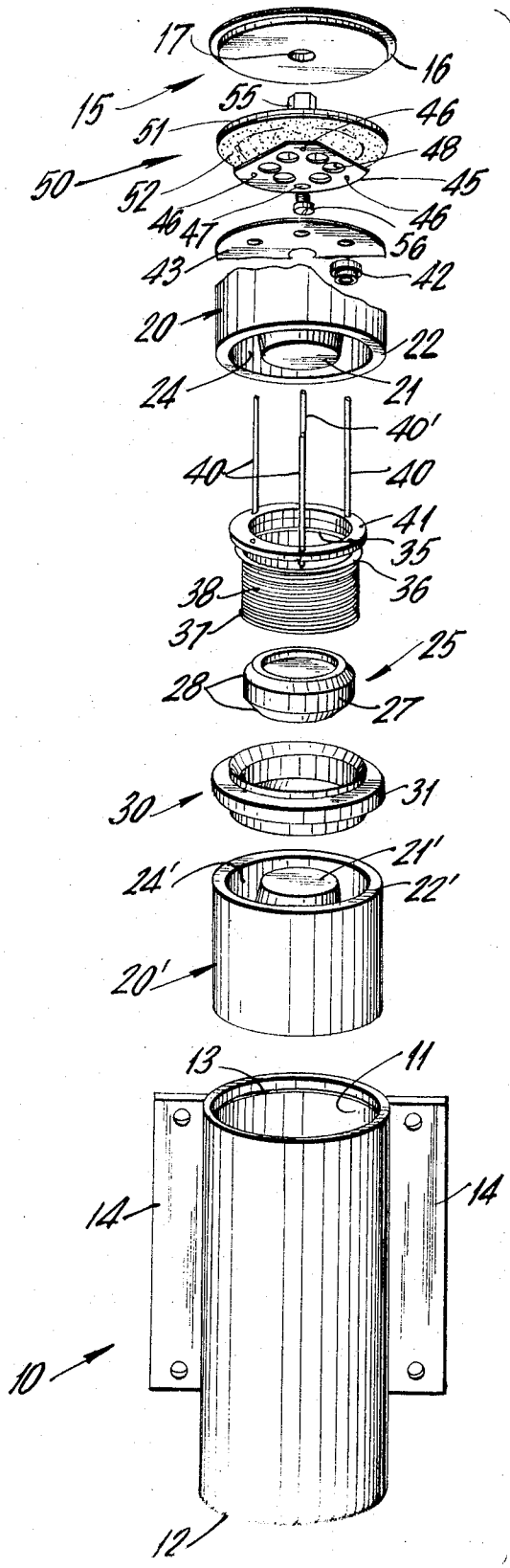

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FIG. 1

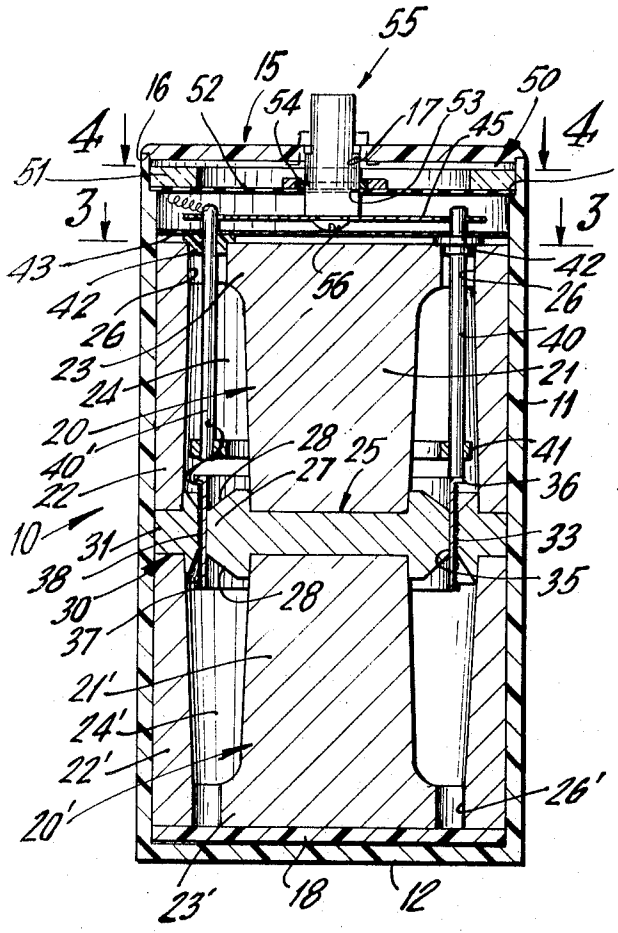


FIG. 2

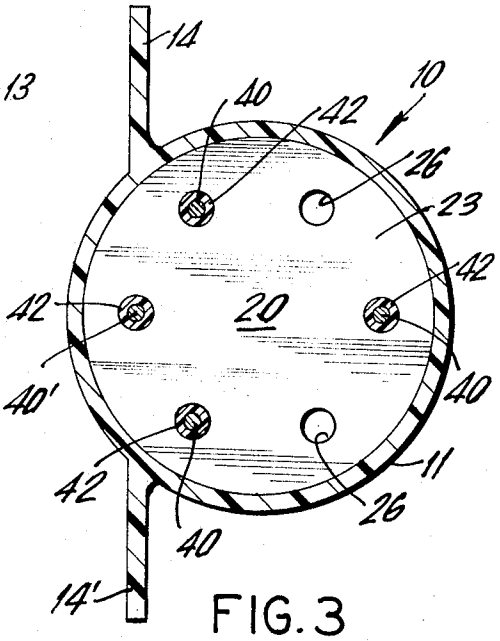


FIG. 3

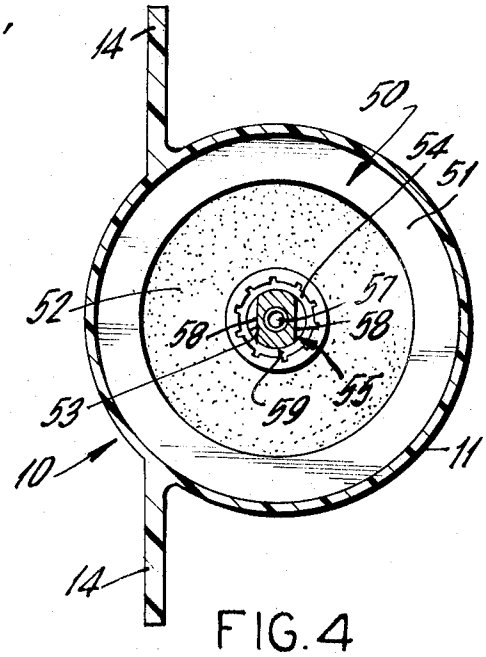


FIG. 4

PERMANENT MAGNET SOLENOID DEVICE

BACKGROUND OF THE INVENTION

There are many applications where it is required that a high force, acting through a short distance, must be provided with a minimum of input or energy, such as electrical energy. Among such applications are trigger devices for missiles where low weight is essential and where a very high capacity source of electric potential is not available.

SUMMARY OF THE INVENTION

This invention relates to permanent magnet solenoid devices and, more particularly, to a novel, improved, compact and simplified permanent magnet solenoid device capable of exerting, when energized, a high force through a small distance and with a minimum consumption of electrical energy.

In accordance with the invention, a pair of high power substantially identical cylindrical permanent magnets are arranged in axially aligned and spaced opposing relation in a close fitting housing of non-magnetic materials such as, for example, a plastic composition material. Preferably, the housing is cup-shaped having a diametrically extending bottom wall which is preferably integral with its cylindrical side wall. The other end of the housing is arranged to be closed by a cover having a central aperture therethrough and arranged to be sealed to the side wall of the housing.

Each permanent magnet has a central cylindrical pole of one polarity, such as a north polarity, and an annular pole of the opposite polarity, such as a south polarity, and is formed integrally with a base interconnecting its poles at the end remote from the other permanent magnet. Thus, for example, the base of one magnet seats against the closed bottom wall of the housing, and the base of the other magnet is adjacent the initially open end of the housing. The bases of the magnets form the bases of respective open annular grooves separating the two poles of the associated magnet, these grooves widening from the base of the magnet toward the other end thereof. For a purpose to be described, the base of each magnet is formed with a plurality of apertures therethrough arranged in equiangular spaced relation at the bottom of each annular groove.

A substantially flat inner circular pole piece is interposed between and in engagement with the facing ends of the cylindrical magnet poles, and has an annular shoulder embracing these poles so that, in diametric cross section, the inner circular pole piece has an I-beam shape with beveled outer surfaces. A substantially flat outer annular pole piece is interposed between the facing ends of the annular poles, having an outer diameter equal to that of the two permanent magnets and having a radially inner shoulder thereon seating into the two facing annular grooves in the magnets. The two pole pieces define therebetween an annular air gap having a very small radial dimension such as, for example, an air gap of 0.10 – 0.20 inches.

A cylindrical bobbin or winding form, having flanges on its axially opposite ends, is seated in the air gap, and is formed of non-magnetic material such as, for example, brass. A moving coil type of winding is wound on this bobbin and preferably has one terminal electrically connected to the bobbin for connection to an external ground. Three equally angular spaced pins of non-magnetic material, such as brass or the like, are mechanically secured to one flange of the bobbin and extend through insulating bushings seated in the apertures in the base of the permanent magnet adjacent the initially open end of the casing, and through apertures in a dielectric guide ring adjacent their inner ends. These pins have a close conforming fit through equally angular spaced apertures in an outer guide or positioning ring of non-magnetic material such as, for example, plastic composition material. The electrical connection to the opposite terminal of the winding on the bobbin is effected by soldering or brazing the free end of the winding to an additional brass lead pin whose inner end sets into and terminates at the inner guide ring. The two guide rings form a movable unit with the brass pins.

A brass plate is secured to the outer ends of the three pins, and is in the form of a circle having two equal segments cut therefrom to provide chords extending at equal angles to a diameter of the circle. This brass plate is formed with three relatively small diameter threaded apertures to receive the ends of the pins, and may be formed with a larger aperture, at the same radius as the pins, to receive, with clearance, the aforementioned lead pin. To decrease air resistance, the plate is formed with a number of relatively large diameter apertures.

The open end of the casing is formed with a seat for a sealing washer which consists of a relatively rigid plastic composition annular ring to which is bonded a thin flexible diaphragm formed preferably of surgical latex rubber. This diaphragm has a central aperture therein bounded by an O-ring which is bonded to the diaphragm. A metal operator, in the form of a substantially cylindrical plunger, is secured to the brass plate by a screw or the like threaded into an aperture in the plunger, and the plunger extends, with slight clearance through the O-ring and outwardly through an aperture in the cover which is sealed to the open end of the cylindrical casing after assembly of the device. The outer end of the plunger may have a threaded aperture, and the plunger may have flattened sides for securing a trigger or link to the plunger for operation by the solenoid.

An object of the invention is to provide an improved permanent magnet solenoid device.

Another object of the invention is to provide such a solenoid device which is capable of exerting a great force through a small distance, when energized.

A further object of the invention is to provide such a device which requires only a very small amount of electrical energy for its operation.

Another object of the invention is to provide such a device which comprises a pair of identical permanent magnets having pole pieces inserted between their facing ends and defining a very small air gap receiving a moving coil type of winding connected mechanically to an operator.

A further object of the invention is to provide such a device which is small, compact, efficient and inexpensive, and which is well adapted for use in operating the trigger of a missile, for example.

For an understanding of the principles of the invention, reference is made to the following description of a typical embodiment thereof as illustrated in the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing:

FIG. 1 is an exploded view of a permanent magnet solenoid device embodying the invention;

FIG. 2 is an axial sectional view through the device;

FIG. 3 is a diametric sectional view taken on the line 3—3 of FIG. 2; and

FIG. 4 is a diametric sectional view taken on the line 4—4 of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawing, the permanent magnet solenoid device embodying the invention is mounted within a casing **10** having a cylindrical side wall **11** and a bottom wall **12** closing one end of the casing and preferably integral with side wall **11.** The open end of the casing is formed with an annular shoulder **13,** and casing **10** has mounting flanges **14** formed with suitable apertures for securing the casing in position. After assembly of the several components of the device within casing **10,** the casing is sealed by a cover **15** which has a shoulder **16** mating with the shoulder **13** and is formed with a central aperture **17** for a purpose to be described.

The essential components of the device include a pair of identical permanent magnets **20** and **20'**, of high magnetic power, which cooperate, through pole pieces to be described hereinafter, with a moving coil winding **38** wound on a bobbin **35.** As the two permanent magnets are identical, only the permanent magnet **20** will be described in detail. The magnet **20'** is seated on a plate **18** in turn seated on bottom wall **12** of casing **10,** plate **18** being made of non-magnetic material such as, for example, a plastic composition material.

Magnets **20** and **20'** are arranged in facing relation within casing **10,** and have a very close fit therein, with magnet **20'** being adjacent wall **12** and magnet **20** being adjacent the open end of casing **10.** Permanent magnet **20** has a central cylindrical pole **21** and an annular outer pole **22,** the two poles being of opposite polarity with pole **21** preferably being a north pole and pole **22** preferably being a south pole. The two poles are interconnected by a base **23,** forming part of the magnetic circuit, and define between them an annular groove **24** which increases in radial dimension outwardly from base **23.** Base **23** is formed with a series of equally angular spaced apertures **26,** such as, for example, six apertures at 60° spacing from each other. Permanent magnet **20'** is identical in construction with permanent magnet **20.**

Within casing **10,** permanent magnets **20** and **20'** are arranged in axially spaced relation to receive therebetween an inner or north circular pole piece **25** and an outer or south annular pole piece **30.** The axial thicknesses of pole pieces **25** and **30** are substantially identical, and pole piece **25** is formed with a peripheral rib **27** closely embracing and conforming to pole pieces **21** and **21'**. The surfaces of rib **27** are beveled as indicated at **28.** Pole piece **30** has an outer diameter equal to the outer diameter of permanent magnets **20** and **20'** and an inner diameter of cylindrical wall of casing **10.** Pole piece **30** is formed with an inner annular rib **31** which closely and conformingly engages the radial inner surfaces of annular poles **22** and **22'**. Pole pieces **25** and **30** define a very small air gap **33** which may be 0.010 – 0.020 inches in radial dimension. A cylindrical bobbin or winding form **35,** of non-magnetic material such as brass or the like, is arranged in air gap **33** and carries a moving coil winding **38** disposed between an upper flange **36** and a lower flange **37.** Flange **36** is substantially wider radially than flange **37,** and is formed with a series of equal angularly spaced apertures each receiving an elongated brass pin **40** which is brazed or soldered to flange **36.** In the illustrated example, there are three pins **40** arranged at angular spacings of 60°A fourth pin **40'** serves as a lead for winding **38,** but is not connected electrically to winding form **35.** One terminal of winding **38** is secured to winding form **35,** and the other terminal is secured to pin **40'**.

As viewed in FIG. **2,** pins **40** extend upwardly from form **35** and with a close fit through apertures in a guide ring **41** of non-magnetic material, such as a plastic composition material. The pins **40** then extend through apertures **26** of permanent magnet **20** and through insulating bushings **42** seated in these apertures and then through apertures in an insulating or dielectric ring **43.** The upper ends of pins **40** are threaded into apertures **46** located at equal angular intervals in a truncated circular brass plate **45.** Brass plate **45** is truncated by severing two circular segments therefrom, with the chords of these segments being equal in length and extending at equal angles to a diameter of plate **45.** A further and much larger aperture **47** is provided for the passage of lead pin **40'** through plate **45,** the inner end of pin **40** being fixed to and terminating at ring **41.** To reduce air resistance, brass plate **45** is formed with a series, such as six, of relatively large diameter apertures **48.**

A sealing washer **50** is seated on shoulder **13** of casing **10,** and held seated on the shoulder by the shoulder **16** of cover **15** when cover **15** is sealed to casing **10.** Sealing washer **50** comprises a ring **51** of plastic composition material to the undersurface of which is sealed a diaphragm **52** of surgical latex rubber, having a central aperture **53** surrounded by an O-ring **54** sealed to diaphragm **52.** The lower end of operator **55** has a threaded aperture receiving a screw **56** extending through a central aperture in brass plate **45.** Operator **55** is secured to move with diaphragm **52** of sealing washer **50** by virtue of a sealing means interconnecting operator **55** to O-ring **54.** The outer end of operator **55** extends outwardly through the aperture **17** in cover **15,** with some little clearance, and has a threaded aperture **57** whereby suitable mechanical linkage or the like may be secured to operator **55.** Such securing is also facilitated by the provision of flats **58** on the otherwise cylindrical operator **55.**

When a potential is applied to winding **38,** the winding is energized and, in cooperation with the magnetic field produce across air gap **33** between inner and outer pole pieces **25** and **30,** respectively, by permanent magnets **20** and **20'**, effects an axial displacement of bobbin **35,** pins **40,** brass plate **45** and operator **55** to perform a desired mechanical function such as, for example the triggering of a missile. In actual practice, the supply of six millijoules of electrical energy to winding **38** will move eight ounces through 0.1 inch. The device is compact and it operating parts are sealed against the ambient influences, with only leads for energizing winding **38** being brought into the casing **10** sealed by cover **15.**

While a specific embodiment of the invention has been shown and described in detail to illustrate the application of the principles of the invention, it will be un-

derstood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. A permanent magnet solenoid device comprising, in combination, a pair of substantially identical permanent magnet means arranged in axially aligned and axially spaced opposing relation, each permanent magnet means including a central cylindrical pole of one polarity and an annular pole of the opposite polarity forming, with the central pole, an open annular groove separating the two poles; and inner substantially circular pole piece interposed between the facing ends of said cylindrical poles; an outer annular pole piece interposed between the facing ends of said annular poles; said inner and outer pole pieces defining therebetween an annular air gap having a very small radial dimension; a substantially cylindrical moving coil winding means positioned in said air gap; a mechanical operator connected to said winding means for axial movement with the latter; and circuit means connected to said winding means to apply an electric potential thereacross to effect axial movement of said winding means and said operator.

2. A permanent magnet solenoid device, as claimed in claim 1, in which said pair of substantially identical permanent magnet means comprises a pair of substantially identical cylindrical permanent magnets each having a base interconnecting its central and annular poles at the ends of the permanent magnet remote from the other permanent magnet, and forming the base of an open annular groove separating its two poles; and connecting means interconnecting said winding means and said operator and extending through the annular groove and through apertures in the base of one of said permanent magnets; said operator being located axially outwardly of said one permanent magnet.

3. A permanent magnet solenoid device, as claimed in claim 2, in which said winding means comprises a winding form of non-magnetic material and a moving coil winding wound on said form; said connecting means including pins of non-magnetic material connected to said winding form and extending outwardly through apertures in the base of said one permanent magnet, and including means interconnecting the outer ends of said pins and connected to said operator.

4. A permanent magnet solenoid device, as claimed in claim 3, in which said winding form and said pins are formed of electrically conductive, non-magnetic metal; a ring of dielectric material positioned axially adjacent said winding form and having apertures closely embracing said pins; a further pin secured to said ring and terminating thereat, said further pin extending outwardly through an aperture in the base of said one permanent magnet; one terminal of said winding being electrically connected to said winding form and the other terminal of said winding being electrically connected to said further pin.

5. A permanent magnet solenoid device, as claimed in claim 4, including a cylindrical casing closely embracing said permanent magnets and said outer annular pole piece, and having a closed bottom wall seating the base of the other of said permanent magnets, said casing having an open outer end; and a cover enclosing said open outer end of said casing and sealed to said casing; said cover being formed with an aperture and said operator extending outwardly through said cover aperture.

6. A permanent magnet solenoid device, as claimed in claim 5, in which said pins extend through dielectric bushings seated in the apertures of the base of said one permanent magnet.

7. A permanent magnet solenoid device, as claimed in claim 6, including a dielectric guide ring adjacent the outer surface of the base of said one permanent magnet and formed with apertures through which said pins extend.

8. A permanent magnet solenoid device, as claimed in claim 5, in which said means interconnecting the outer ends of said pins comprises a plate of electrically conductive material; the open outer end of said casing being formed with an annular shoulder on its inner surface; and a sealing washer seated in said annular shoulder and including a sealing diaphragm having a central aperture therethrough; said operator comprising a substantially cylindrical metal member having its inner end secured to said electrically conductive plate and extending through the aperture in said diaphragm and the aperture in said cover; said operator being sealed to said flexible diaphragm at said aperture therein.

9. A permanent magnet solenoid device, as claimed in claim 8, in which said sealing washer comprises a relatively rigid ring of dielectric material seated in said annular shoulder; said diaphragm comprising a thin sheet of elastomeric material stretched across and sealed to said last-named dielectric ring; and an O-ring sealed to said diaphragm concentrically with the opening therein and sealed to said operator.

10. A permanent magnet solenoid device, as claimed in claim 9, in which the outer end of said operator is formed for mechanical connection to means operated by said device.

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