

[54] ELECTROMAGNETIC DEVICE

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335/230

[51] Int. Cl. **H02k 33/00**

[58] Field of Search 310/36-39, 156;
335/229, 230, 234; 251/65, 129; 324/146

[56] **References Cited**

UNITED STATES PATENTS

3,206,160 9/1965 Bennett 335/229 X
3,538,358 11/1970 Baverle 310/36 X

2,569,800 10/1951 Cataldo 251/65 X

FOREIGN PATENTS OR APPLICATIONS

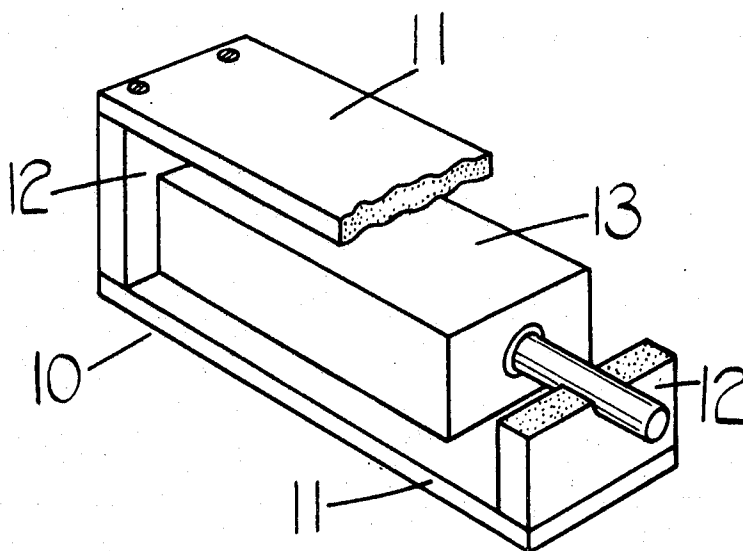
371,432 4/1932 Great Britain 310/39

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[57] **ABSTRACT**

An electro-magnetic torque motor has a permanent magnet pivotally mounted in a hollow frame of magnetisable material. Surrounding the magnet within the frame is a winding whose magnetic axis is angularly displaced from the magnetic axis of the magnet when the winding is not energised. Energisation of the winding tends to rotate the magnet within the winding in a direction to align the magnetic axes.

10 Claims, 9 Drawing Figures



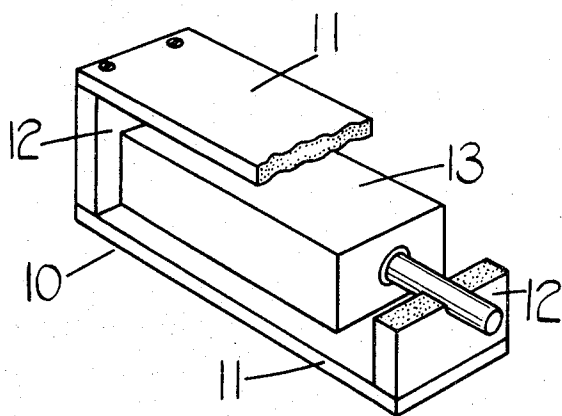


FIG. 1.

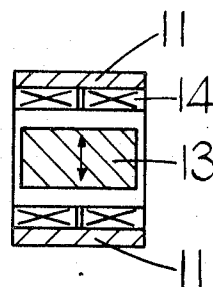


FIG. 2.

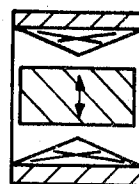


FIG. 3.

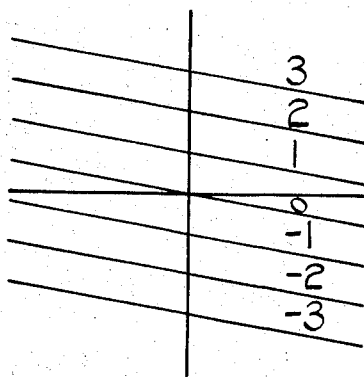


FIG. 4.



FIG. 5.

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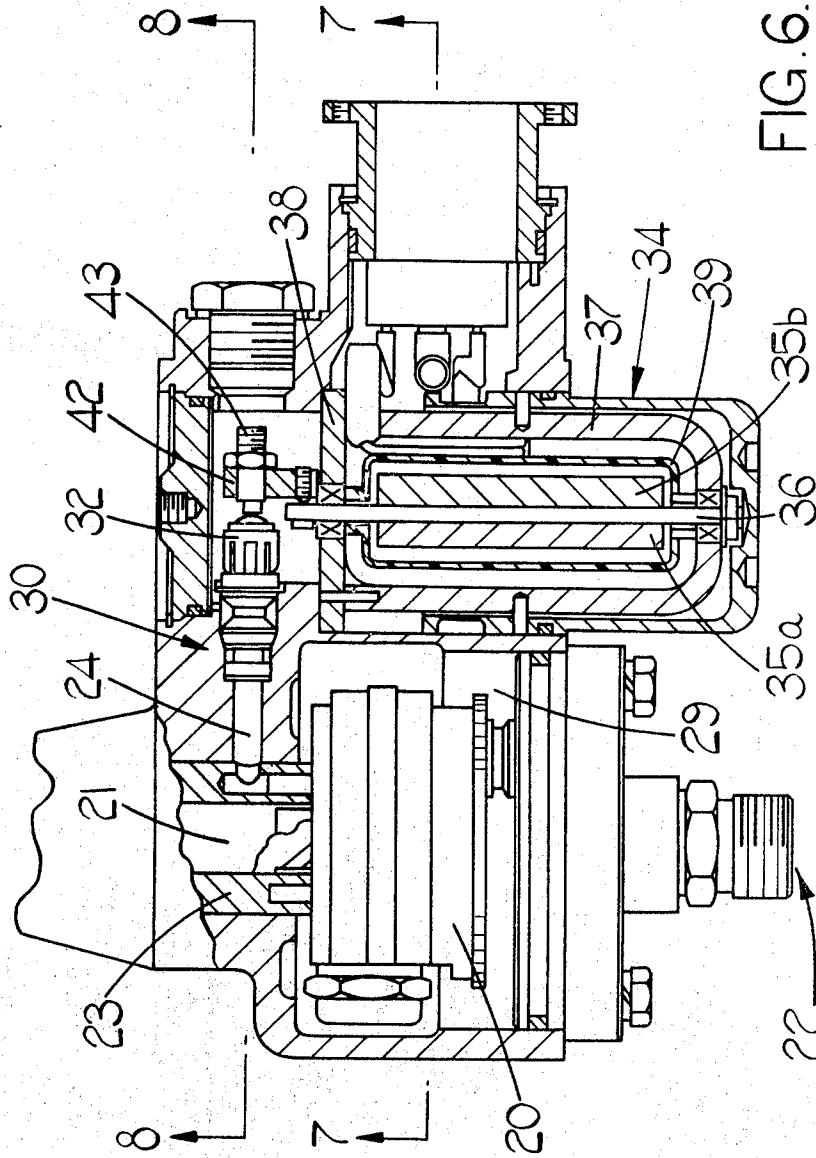


FIG. 6.

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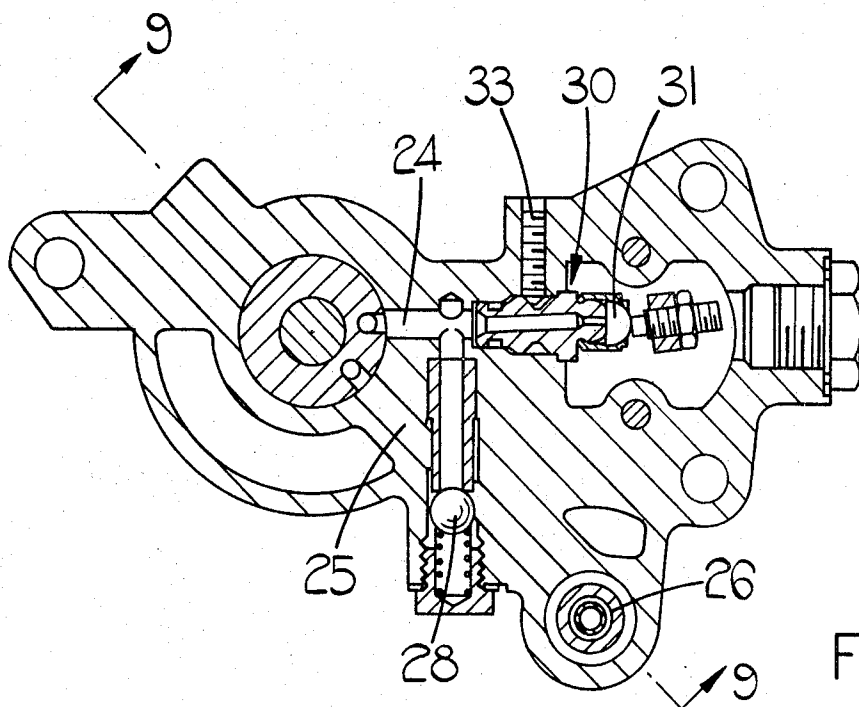


FIG. 8.

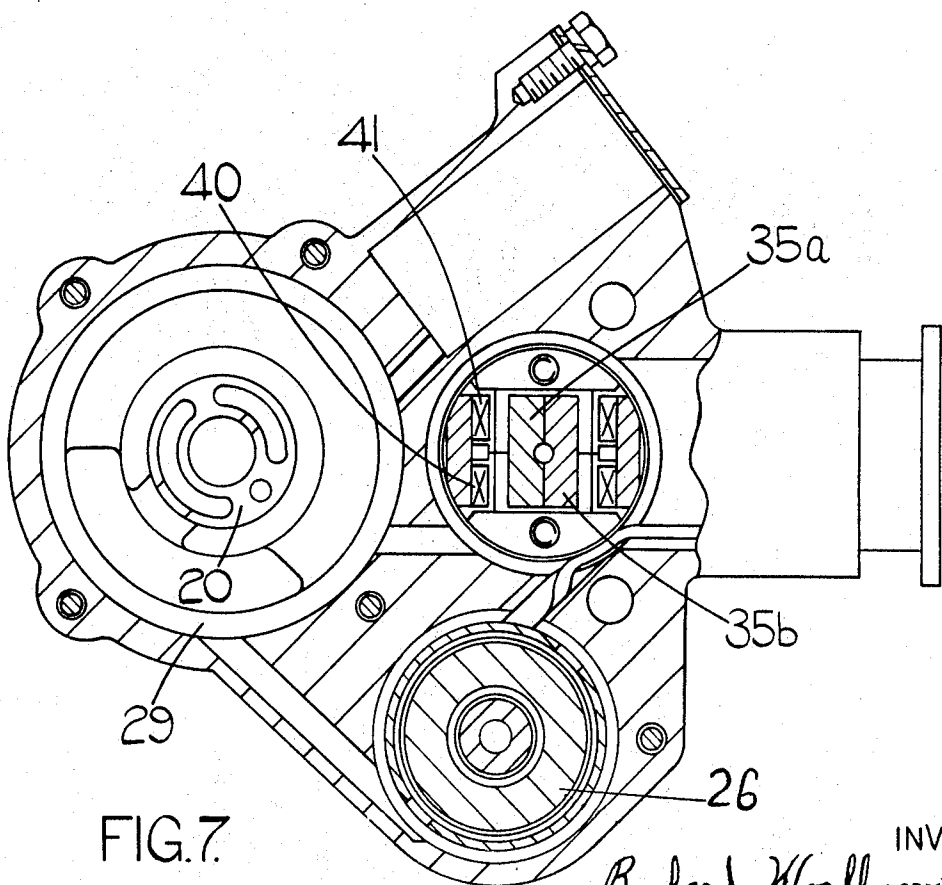


FIG. 7.

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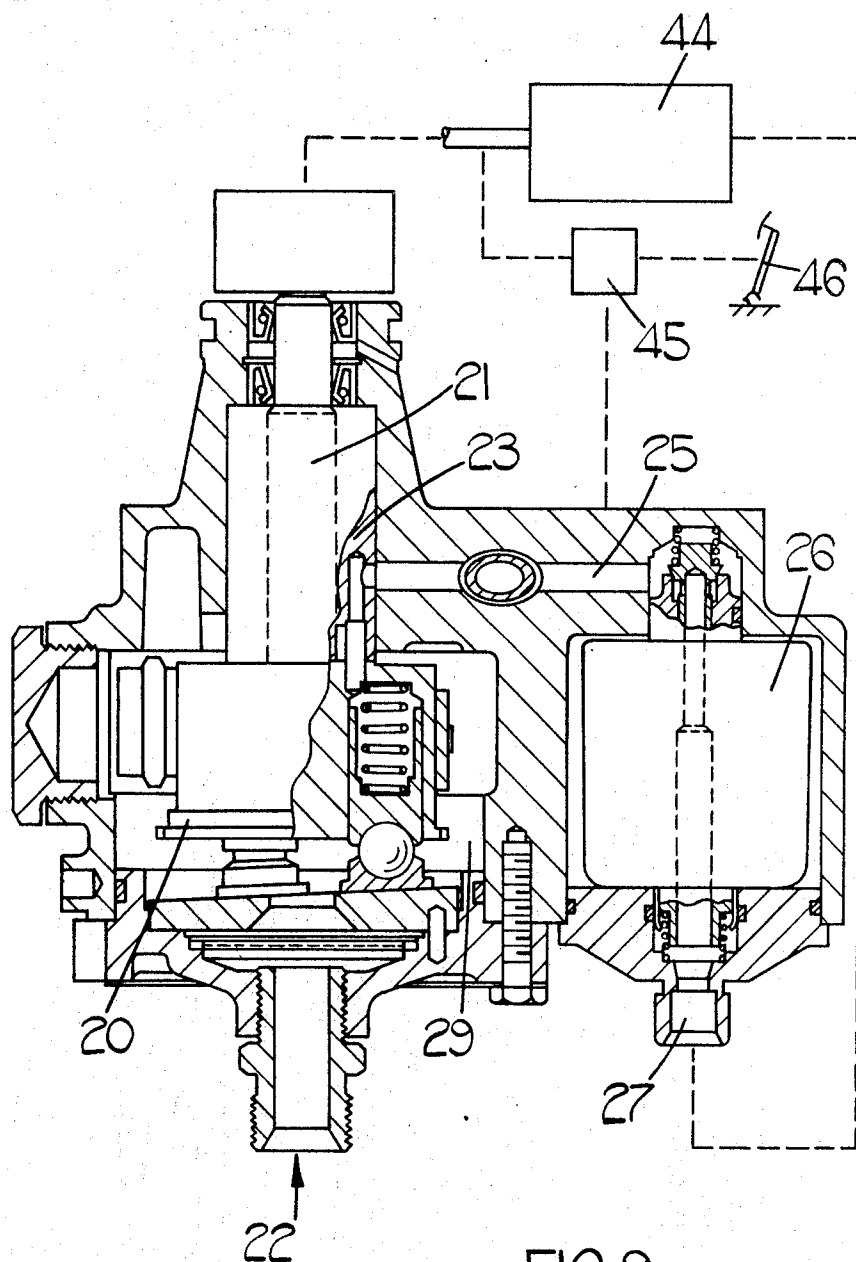


FIG. 9.

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ELECTROMAGNETIC DEVICE

This invention relates to an electromagnetic device of the kind known as torque motors and the object of the invention is to provide such a device in a simple and convenient form.

According to the invention a device of the kind specified comprises in combination a frame formed from a material of high magnetic permeability and defining an internal cavity, a permanent magnet pivotally mounted within said cavity, and a winding disposed in said cavity, the arrangement being such that when the winding is energised the magnet will tend to turn about its pivot axis so that its magnetic axis will be aligned with that of the winding.

Examples of electromagnetic devices in accordance with the invention will now be described with reference to the accompanying drawings in which:

FIG. 1 shows a cut away perspective view of part of the device,

FIG. 2 is a section through the complete device of FIG. 1,

FIGS. 3 and 5 are views similar to FIG. 2 showing modifications,

FIG. 4 is a plot of torque against angle for different values of current,

FIG. 6 is a section through an arrangement incorporating a device according to the invention,

FIGS. 7 and 8 are sections on the corresponding lines in FIG. 6, and

FIG. 9 is a section on line 9—9 in FIG. 8.

Referring to FIGS. 1 and 2 of the drawings the device comprises a frame 10 which includes a pair of elongated side members 11 which in a preferred embodiment have a substantially rectangular shape, and a pair of end members 12. At least the elongated members 11 are formed from magnetizable material in the form of soft iron. The frame defines a cavity in which is located a bar-shaped permanent magnet 13, having its longitudinal length and broad side parallel with the elongated side members 11, the magnet being mounted for pivotal movement within the cavity. With this arrangement, it can clearly be seen (FIGS. 1 and 2) that the magnetic axis of the permanent magnet extends vertically while the magnetic axis of the coil extends horizontally. Moreover, the magnet 13 is polarized so that its broad faces which are presented to the members 11 are of opposite polarity and the effect of this is that the magnet will try to assume the position in which it is shown, that is a position of minimum reluctance in the flux path from the magnet 13.

Mounted within the frame is a winding 14 which for ease of assembly is formed in two parts. The winding extends around the internal surfaces of the members 11 so that its magnetic axis is normal to the pivot axis of the magnet and parallel to the planes containing the surfaces of the members 11. When the winding is energised the magnet tends to pivot about its axis so that its magnetic axis becomes aligned with that of the winding 14. The winding 14 may be shaped as shown in FIG. 3 to permit the magnet greater angular movement and to concentrate the windings of the coil in the position where the magnetic field between the magnet and the frame is strongest.

The type of characteristic obtained is shown in FIG. 4 in which the torque is plotted against the angle of the magnet for varying values of current. The slope of the

zero current curve can be defined as the stiffness and the value of the stiffness can be varied by varying the proportions of the devices.

In the construction shown in FIG. 5 the magnet and the inner face of the frame are cylindrical. In this manner the speed of response is increased since the moment of inertia of the magnet is reduced. In a modification of the device shown in FIG. 5 the frame is of hollow cylindrical form and in this case the stiffness is zero.

Shown in FIGS. 6, 7, 8 and 9 is a combined fuel pump and control valve arrangement for an internal combustion engine, incorporating an axial piston pump 20 rotatable by a shaft 21 to draw fluid from an inlet 22 and discharge it via a port block 23. Block 23 has a pair of outlet passages 24, 25. Passage 25 communicates via a solenoid shut-off valve 26 with an outlet connection 27 for the arrangement.

Passage 24 communicates via a relief valve 28 with a chamber 29 surrounding the pump 20, and hence with the inlet 22. Passage 24 also provides an inlet for a spill valve 30 in parallel with relief valve 28 and having a half ball closure member 31. Member 31 is rendered captive on the remainder of valve 30 by a cage 32. Valve 30 is removably located in the remainder of the arrangement by means of a grub screw 33.

A torque motor 34, according to the invention, has a magnet 35 formed in two parts 35a, 35b secured to a spindle 36 for pivotal movement about an axis which passes through the axis of valve 30 and is spaced from the circumference of the closure member 31. Spindle 36 is mounted between a U-shaped frame member 37 and a further end frame member 38. Members 37, 38 also support a plastics former 39 for a pair of coils 40, 41. Coils 40, 41 effectively form a single winding whose magnetic axis is perpendicular to the axis of spindle 36 and lies parallel to the planes of the limbs of frame member 37.

Secured to spindle 36 is a bracket 42 through which extends a stud 43. Stud 43 engages the circumference of closure member 31 to shut valve 30 when stud 43 and valve 30 are axially aligned. Rotation of spindle 36 from its central position permits closure member 31 to lift and open valve 30. Supply of fuel to the associated engine 44 is dependent on the amount of fuel spilled through valve 30. Torque motor 34 is responsive to electrical signals from a device 45 associated with engine 44. Signals from device 45 are in turn dependent on the difference between actual engine speed and the setting of a speed control 46 for the engine.

I claim:

1. An electro magnetic torque motor comprising a frame formed from a material of high magnetic permeability and defining an internal cavity, said frame including a pair of side members extending in planes which are substantially mutually parallel, a permanent magnet mounted within said cavity for pivotal movement about an axis substantially parallel to the planes of said side members, the faces of the magnet adjacent the side members being of opposite polarity, so that in the absence of an external force on said magnet the latter moves towards an equilibrium position, relative to said frame, in which there is minimum reluctance in the flux path from the magnet, and a winding disposed in said cavity, the winding having a magnetic access which is substantially perpendicular to the pivotal access of the magnet and substantially parallel to the planes of

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the side members, the arrangement being such that when the winding energised the magnet will tend to turn about its pivotal axis away from equilibrium position to a position in which its magnetic axis will be aligned with that of the winding.

2. A torque motor as claimed in claim 1 in which the magnet has a substantially rectangular cross section perpendicular to its pivotal axis.

3. A torque motor as claimed in claim 2 in which the winding has a substantially triangular cross section perpendicular to the pivotal axis of the magnet.

4. A torque motor as claimed in claim 1 in which the surface of the magnet adjacent the windings is a surface of revolution centred on the pivotal axis of the magnet.

5. A torque motor as claimed in claim 4 in which the magnet is substantially cylindrical.

6. A torque motor as claimed in claim 4 in which the side members are part cylindrical.

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7. A torque motor as claimed in claim 4 in which the windings define surfaces which lie closely adjacent the surfaces of revolution of the magnet.

8. A fluid flow control valve comprising an inlet, an outlet, a torque motor as claimed in claim 1, a spindle rotatable by the magnet, a projection on the spindle and a valve closure member between the inlet and the outlet and engageable by the projection to shut the valve when the spindle is in one angular position, the closure member being movable in response to a pressure at the inlet to open the valve in other angular positions of the spindle.

9. A valve as claimed in claim 1 in which the closure member is a half ball and the projection is engageable with the part-spherical surface of the half ball.

10. A valve as claimed in claim 9 in which the axis of the said spindle is spaced from the said part-spherical surface.

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