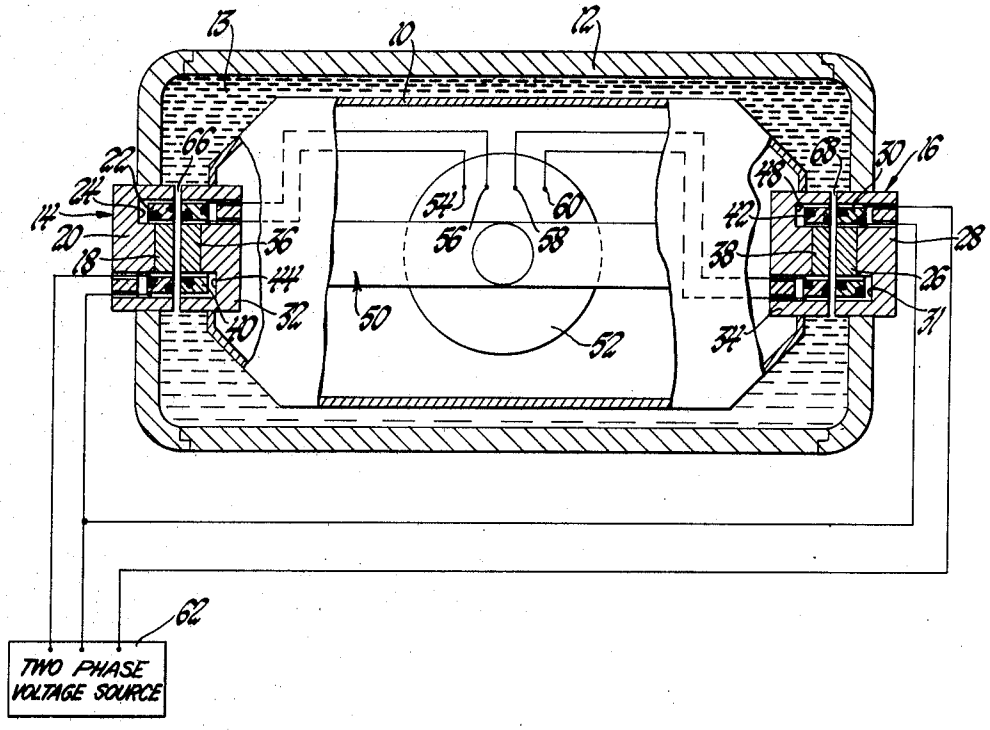
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COMBINED MAGNETIC SUSPENSION AND TRANSFORMER

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COMBINED MAGNETIC SUSPENSION AND TRANSFORMER

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This invention relates to a transformer in combination with an apparatus for magnetically suspending a body and with means for providing electrical power to the body without the use of flexible leads.

It is often desirable in applications wherein a body is magnetically suspended to provide electrical power to the suspended body, such as for energizing windings of a motor mounted within the suspended body. Flexible mechanical leads could be used for supplying the electrical power to the suspended body; however, such leads might limit angular excursion of the suspended body and exert reaction torques acting on the suspended body.

In accordance with this invention, electrical power is provided to a magnetically suspended body without the use of flexible mechanical leads. This is accomplished by magnetically suspending a body between two electromagnets each excited by A.C. voltage. A secondary winding is provided on the suspended body whereby voltage is induced in the winding due to the magnetic field generated by one of the electromagnets and related in phase to the voltage exciting the electromagnet. Accordingly, A.C. voltage is provided to the suspended body.

A more complete understanding of this invention may be had from the detailed description which follows taken in conjunction with the drawing shown in the single figure illustrating a plan view partly in section of one embodiment of the invention.

Referring now to the single figure there is shown an illustrative embodiment of the invention. A cylindrically shaped hollow body **10** which may take the form of a gyroscope float is magnetically suspended within a cylindrically shaped hollow casing **12** between two coaxially disposed electromagnets **14** and **16**. A viscous fluid **13** fills the spacing between the body **10** and the casing **12** so as to provide a degree of buoyancy for the body **10** as well as viscous damping. The electromagnet **14** comprises a cylindrically shaped magnet pole piece **18** mounted on a ferrite cup **20** suitably secured to the casing **12** and an electromagnet coil **22** mounted in an annular groove **24** in the cup **20**. The electromagnet **16** comprises a cylindrically shaped magnetic pole piece **26** mounted on a ferrite cup **28** suitably secured to the casing **12** and an electromagnet coil **30** mounted in an annular groove **31** in the cup **28**. The body **10** has mounted thereon two coaxially disposed ferrite cups **32** and **34** having respectively mounted thereon cylindrically shaped magnetic armatures **36** and **38**. Secondary windings **40** and **42** are respectively mounted in annular grooves **44** and **48** in the cups **32** and **34**, respectively. A gimbal assembly **50** is mounted with the inner side of the casing **10** and supports a two-phase motor **52** which is provided for rotatably driving an inertial element within the casing **10**. The secondary winding **40** is electrically connected with terminals **54** and **56** on the motor **52** and the secondary winding **42** is electrically connected with the terminals **58** and **60** on the motor **52**. Each of the electromagnet coils **22** and **30** are connected across a different phase of a constant voltage two phase A.C. voltage source **62**.

The voltage source **62** provides alternating current flow in the coils **22** and **30** of the electromagnets **14** and **16**, respectively, creating magnetic forces which act on the body **10** to support it. The magnetic flux created by

the electromagnet **14** flows as follows: from the pole piece **18** across a gap **66**, the armature **36**, the ferrite cup **32**, across the gap **66**, the ferrite cup **20** and back to the pole piece **18**. Similarly, the magnetic flux created by the electromagnet **16** flows as follows: from the pole piece **26** across a gap **68**, the armature **38**, the ferrite cup **34**, across the gap **68**, the ferrite cup **28** and back to the pole piece **26**.

If the body **10** is axially displaced there will result a change in length of gaps **66** and **68** between the pole piece **18** and the armature **36** and the pole piece **26** and the armature **38**, respectively, resulting in a change in the reluctance of the flux path of each gap. This will result in a change in inductance of the coil of each electromagnet causing the current flowing therein to change and thus in turn causing a change in the attractive magnetic forces between the electromagnets and the armatures. For example, if the body **10** is axially displaced to the left in the single figure, the length of gap **66** will decrease and the length of gap **68** will increase. Thus the reluctance of the flux path in the gap **66** will decrease resulting in an increase in the inductance of coil **22** whereas the reluctance of the flux path in the gap **68** will increase resulting in a decrease in the inductance of coil **30**. Since constant alternating voltage from source **62** is applied across the coils **22** and **30** the current flowing in coil **22** will decrease and the current flowing in coil **30** will increase. Hence the magnetomotive force created by the current flowing in coil **22** will decrease and the magnetomotive force created by the current flowing in coil **30** will increase resulting in a net axial magnetic force acting on the body **10** so as to axially recenter it between the electromagnets **14** and **16**.

If the body **10** is displaced radially of its axis of symmetry with respect to the electromagnets **14** and **16** there will result a decrease in overlapping area between the pole piece **18** and the armature **36** and between the pole piece **26** and the armature **38** whereby the flux lines will crowd together in the areas of minimum reluctance. Since the electromagnets **14** and **16** are excited by constant alternating voltage from source **62** such changes in reluctance will result in forces being set up so as to act on the armatures **36** and **38** in a direction to decrease the reluctance and increase the permeance of gaps **66** and **68**, respectively. Thus, the armatures will be moved toward the configuration of minimum reluctance so as to radially recenter the body **10** with respect to the pole pieces **18** and **26** of the electromagnets **14** and **16**, respectively.

Whereas the embodiment of the invention shown in the single figure has been described with respect to a particular magnetic suspension means as described above other arrangements for providing radial and axial magnetic suspension of the body **10** may be used. One such arrangement may take the form of the magnetic suspension system described in U.S. Patent No. 3,146,038, issued August 25, 1964.

In accordance with the present invention, voltages will be induced in the secondary windings **40** and **42** related in phase to the voltages exciting the electromagnet coils **22** and **30**, respectively. For example, the magnetic flux created by the electromagnet **14** will link the secondary winding **40** inducing a voltage therein related in phase to the voltage applied to the electromagnet coil **22** from the two phase voltage source **62**. Similarly, a voltage will be induced in the secondary winding **42** related in phase to the voltage applied to the electromagnet coil **30** from the two phase voltage source **62**. Hence, two phase voltage may be obtained from the secondary windings **40** and **42** and applied to terminals **54** and **56** and **58** and **60** so as to excite the two phase motor **52**.

Although the description of this invention has been given with respect to a particular embodiment, it is not to be construed in a limiting sense. Numerous variations and modifications within the spirit and scope of the invention will now occur to those skilled in the art. For a definition of the invention, reference is made to the appended claims.

I claim:

1. The combination of a magnetic suspension system and power supply transformer for a body which is rotatable about a predetermined axis comprising first and second electromagnets, the electromagnets including respective coils disposed normal to and coaxial with the predetermined axis, a body freely suspended between the electromagnets and including first and second magnetic armatures disposed in magnetic proximity to the first and second electromagnets respectively, a source of alternating voltage connected with each electromagnet for excitation thereof whereby the body is suspended by the attractive magnetic forces between the armatures and the respective electromagnets, a secondary coil disposed on the body coaxially adjacent one of the electromagnet coils and spaced therefrom, means to define a magnetic circuit between said one electromagnet coil and the secondary coil thereby to transfer electrical energy between the coils, electrical load means carried by the body, and output circuit means connecting the secondary coil with the electrical load for energization thereof.

2. The combination of a magnetic suspension system for a body which is adapted for rotation about a predetermined axis, and power supply transformer for an electrical load carried by the body comprising first and second electromagnets, the electromagnets including respective coils disposed normal to and coaxial with the predetermined axis, a freely suspended body having first and second coaxially disposed magnetic armatures mounted thereon and disposed in magnetic proximity the first and second electromagnets respectively, each electromagnet comprising a magnetic pole piece mounted on supporting means and having a coil wound thereon, each coil connected to receive a different phase of a two-phase alternating voltage source for excitation thereby to suspend the body by the attractive magnetic forces between the first electromagnet and the first armature and between the second electromagnet and the second armature, first and second windings wound on the first and second armatures, respectively, coaxially adjacent the first and second electromagnet coils and spaced therefrom by a gap, respective means disposed adjacent the armatures and pole pieces for defining a low reluctance magnetic circuit between each of the coils and the coaxially adjacent windings thereby to transfer electrical energy therebetween, an electric load device carried by the body, and output circuit means connecting the load device with windings for excitation thereof.

3. The combination of a magnetic suspension system

for a body which is adapted for rotation about a predetermined axis, and power supply transformer for an electrical load carried by the body comprising first and second electromagnets, the electromagnets including respective coils disposed normal to and coaxial with the predetermined axis, a freely suspended hollow body having first and second coaxially disposed magnetic armatures mounted thereon and disposed in magnetic proximity to the first and second electromagnets respectively, each electromagnet comprising a magnetic pole piece mounted on supporting means and having a coil wound thereon, each coil connected to receive a different phase of a two-phase alternating voltage source for excitation to suspend whereby the body by the attractive magnetic forces between the first electromagnet and the first armature and between the second electromagnet and the second armature, first and second windings wound on the first and second armatures, respectively, coaxially adjacent the first and second electromagnet coils and spaced therefrom by a gap, respective means disposed adjacent the armatures and pole pieces for defining a low reluctance magnetic circuit between each of the coils and the coaxially adjacent windings thereby to transfer electrical energy therebetween, and a two-phase motor mounted within the body electrically connected with the first and second windings and responsive to the voltages induced therein.

4. A system for suspending a gyro float assembly carrying an electrical load device comprising a housing, a gyro assembly disposed within the housing and rotatable about a predetermined axis, first and second electromagnets disposed on the predetermined axis at opposite ends of the housing and including first and second primary coils, first and second armature means disposed on the axis at opposite ends of the gyro assembly and in magnetic proximity to the first and second electromagnets respectively, a power source for energizing the electromagnets thereby to provide axial restraining forces between the electromagnets and the armature means for supporting the gyro assembly out of contact with the housing, first and second secondary coils mounted on the first and second armature means respectively, the secondary coils being coaxially disposed adjacent the primary coils and separated therefrom by respective gaps, an electrical load device carried by the gyro assembly and circuit means connecting the secondary windings to the load for excitation thereof.

References Cited by the Examiner

UNITED STATES PATENTS

2,809,526	10/57	Lundberg	308—10
2,822,694	2/58	McKenney	308—10
2,828,627	4/58	Gabrielson	74—5
3,079,574	2/63	Garcia	308—10

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,199,932 August 10, 1965

Harold E. Clark

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 45, for "magnet" read -- magnetic --; column 3, line 38, after "proximity" insert -- to --; column 4, line 14, for "to suspend whereby" read -- thereby to suspend --.

Signed and sealed this 19th day of July 1966.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents