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MAGNETIC FLUID ACTUATING PUMP

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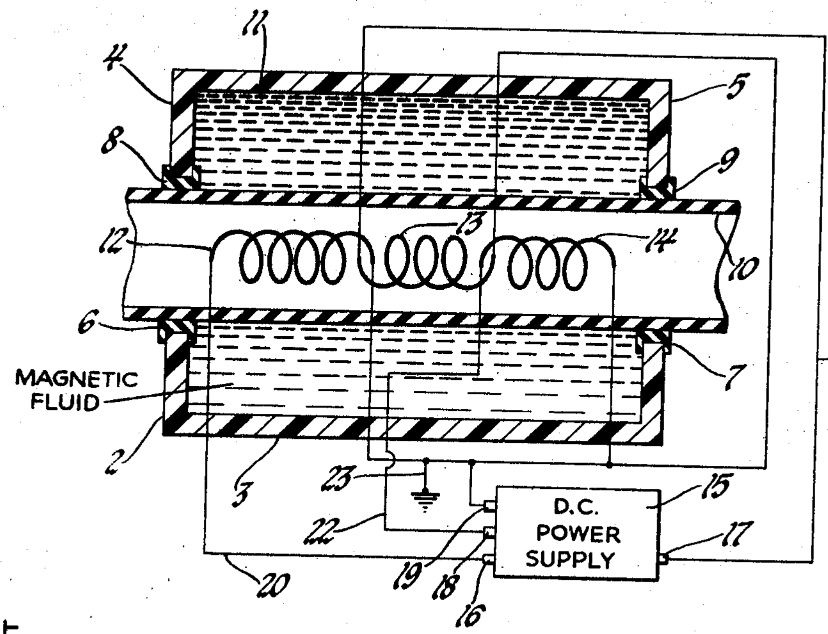

Fig. 1

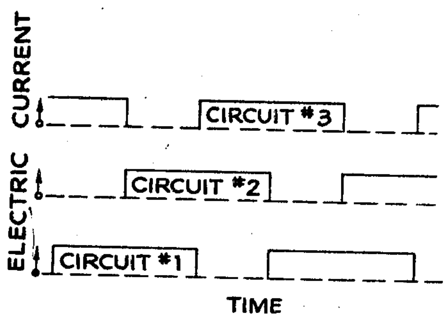

Fig. 2

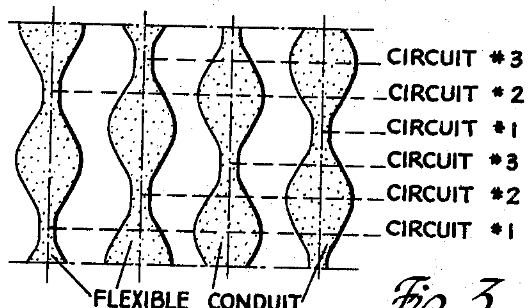

Fig. 3

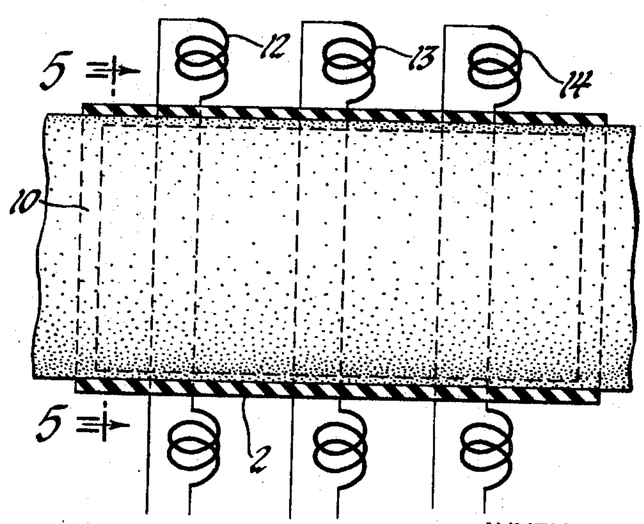

Fig. 4

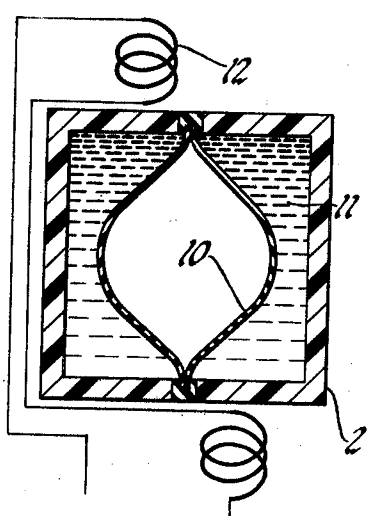

Fig. 5

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MAGNETIC FLUID ACTUATING PUMP

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ABSTRACT OF THE DISCLOSURE

A pump comprising a container having a fluid carrying flexible tube or envelope extending therethrough. Sealed within the container and surrounding the tube is a second fluid, containing finely divided magnetic particles. Positioned either within the tube or externally of the container are a plurality of electric coils that are sequentially energized to provide pulsating magnetic fields. The magnetic fields act upon the fluid containing the magnetic particles, and this fluid in turn acts upon the flexible tube or envelope causing it to periodically collapse and expand whereby a pumping action is exerted on the fluid carried by the tube or envelope.

This invention relates generally to pumps and more particularly to pumps that are actuated by a plurality of magnetic fields.

In general there are two broad categories of electromagnetic pumps. The first is used to pump an electromagnetic conductive fluid such as liquid metals. In this type of pump an electric current may be caused to pass through the fluid, (conductive type pump), or a magnetic field may be caused to act upon the fluid, (inductive type pump).

A second category of electromagnetic pumps includes pumps for fluids other than electromagnetic conductive fluids. It is to this category of pumps that the present invention is directed. In prior art pumps of this type wherein flexible conduits have been caused to collapse and expand in order to provide a pumping action, it has been the practice to either imbed electric current carrying coils within the walls of the flexible conduit, or to imbed magnetizable particles within the conduit walls upon which one or more magnetic fields would act to collapse and expand the conduit.

It is seen that these prior art pumps require specially made flexible conduits for the reason that without uniformed spaced coils or magnetic particles, a non-uniform electromagnetic field gradient may result and reduce the efficiency of the pump.

It is a primary object of the present invention to provide an electromagnetic pump wherein the pumping conduit need not be specially constructed to carry coils or magnetic particles within its walls.

A further object of the present invention is to provide means for using a magnetic fluid for the purpose of compressing a flexible conduit through which a non-magnetic fluid may be pumped.

Another object of the present invention is to provide means for producing three or more magnetic fields for the pump, which means may be varied in position to provide for versatility in the use or application of the pump without decreasing its efficiency.

Another object of the present invention is to eliminate the use of inlet and outlet valves for the pump by employing three or more magnetic fields to operate the pump.

A further object is to provide an electromagnetic pump wherein the flexible or pumping conduit does not require the use of any special means such as a spring or similar device to force the conduit back to its original position in order to continue its peristaltic effect.

These and other objects will become obvious when the present specification is read in connection with the accompanying drawing wherein like numerals refer to like parts and wherein,

FIG. 1 is a vertical sectional view of one embodiment of the present invention;

FIG. 2 is a plot of electric current applied to the coils shown in FIG. 1 versus time;

FIG. 3 is a sketch of the peristaltic effect that the magnetic fields of the coils of FIG. 1 produce on the flexible tube shown in FIG. 1;

FIG. 4 is a cross-sectional view of a preferred embodiment of the present invention, and

FIG. 5 is a cross-section along lines **5**—**5** of FIG. 4.

Referring now to FIG. 1, a fluid container **2** which is substantially inflexible, has walls including a side portion **3** and rigid end members **4** and **5**. The container may be metallic or may be constructed of any suitable rigid plastic material. Openings **6** and **7** are provided in the end members and these openings are provided with seals **8** and **9**. A rubber or flexible plastic tube or conduit **10** has a continuous portion that extends through the container **2** and passes through the seals **8** and **9**. A fluid or liquid (not shown) is adapted to be pumped through the conduit **10**.

A second fluid **11** substantially completely fills the container **2** and is maintained within the container by the seals **8** and **9**, and is separated from the pumped fluid by the walls of the conduit **10**. It is noted that the walls of the conduit **10** do not have magnetizable particles, nor electric coils embedded therein and is therefore of simple construction.

The fluid **11** is a magnetic fluid in that it contains magnetizable particles. The fluid may be a ferromagnetic fluid such as a colloidal suspension of submicron-sized ferrite particles in a carrier fluid such as kerosene, with a dispersing agent such as an oleic acid coating on the particles to prevent flocculation.

Electric coils **12**, **13** and **14** overlap and are coaxially and adjustably positioned within the conduit **10**. The coils are preferably cylindrically shaped and have a smooth outer diameter that is smaller than the inner diameter of the flexible conduit. A direct current (D.C.) power supply **15** is provided with four electric terminals **16**, **17**, **18** and **19**, the latter of which is a common or grounded terminal for each of the three coils. To complete the electric circuits for the coils, electric wires or lines **20**, **21**, **22** and **23** are provided.

It is thus seen that the electric circuit for coil **12** (circuit #1) includes coil **12**, line **20** to power supply **15** through terminal **16** and to ground through terminal **19** and line **23**. Circuit #2 for coil **13** includes coil **13**, line **21** to power supply **15** through terminal **17** and to ground through terminal **19** and line **23**. Similarly, circuit #3 for coil **14** includes coil **14**, line **22** to power supply **15** through terminal **18** and to ground through terminal **19** and line **23**.

A contact arm (not shown) connected to terminal **19** and driven by a clock or other timing device may be used in the D.C. power supply to sequentially complete the above described circuits through terminals **16**, **17** and **18**, respectively.

The operation of the pump illustrated in FIG. 1 is best explained with reference to FIGS. 2 and 3. In FIG. 2 it is seen that circuit #1, which includes the coil **12** is the first circuit energized. Prior to the deenergization of circuit #1, circuit #2 including coil **13** is energized. As circuit #1 is deenergized circuit #3 is energized, and circuit #2 remains energized. As each coil is sequentially energized, a magnetic field is periodically established and the magnetic particles in the fluid **11** are attracted to the energized coil to cause that portion of the flexible conduit adjacent the coil to periodically collapse. Since the energization of the coils overlap, overlapping portions of the flexible conduit **10** collapse and a peristaltic effect occurs as indicated in FIG. 3 causing the fluid therein to be pumped through the conduit. Furthermore, in view of the fact that the magnetic fields set up by the coils overlap, no inlet and outlet valves are required since the fluid being pumped through conduit **10** is forced in one direction. The direction of fluid flow will depend upon whether coil **12** or coil **14** is energized first. It is thus seen that the pump is reversible.

Since the chamber **2** is completely filled with a fluid except for that volume occupied by conduit **10**, collapse of the conduit due to the force exerted by the fluid **11** causes a vacuum to occur in the regions above the energized coils. Upon deenergization of the coils, the fluid **11** again fills the vacated space and the conduit **11** returns to its normal shape without the use of springs or similar devices.

The amount of current and voltage required will depend on various factors including the number of turns per each coil, the type of magnetic fluid **11** employed, and the flexibility characteristics of conduit **10**. The amount of time that each coil is energized will depend primarily on the rate of fluid flow desired. The rate or speed of flow is inversely proportional to the energization time.

The embodiment of the invention disclosed in FIGS. 4 and 5, differs from that in FIG. 1 in two primary respects. First, the flexible conduit **10** is in the form of an envelope having somewhat of an elliptical or non-circular cross-sectional area and more importantly the coils **12**, **13** and **14** are positioned externally of the container **2**. This gives a degree in flexibility to the construction of the pump. It is clear that the coils of the embodiment of FIG. 1 could also be external and those of FIGS. 4 and 5 could be internal.

The operation of the pump of FIGS. 4 and 5 is identical with that of FIG. 1 and need not be repeated.

While the present invention has been disclosed in its preferred embodiment it may be obvious to one skilled in the art that slight modification can be made without departing from the scope of the disclosure.

I claim:

1. An electromagnetic pump comprising walls defining a chamber; means providing at least two openings for said chamber; a flexible conduit passing through said openings and having a continuous portion extending through said chamber, said chamber containing a fluid having particles therein capable of being attracted by a magnetic field; means providing a seal between said openings in said chamber and said conduit; and means for periodically establishing a magnetic field along axial portions of said conduit to attract said particles within said chamber toward said conduit, whereby axial portions of said conduit are periodically collapsed.

2. An electromagnetic pump as defined by claim **1** wherein said magnetic field comprises at least three overlapping magnetic fields sequentially established along axial portions of said conduit.

3. An electromagnetic pump as defined by claim **1** wherein said means for periodically establishing said magnetic field comprises three overlapping electric coils axially positioned within said conduit.

4. An electromagnetic pump as defined by claim **1** wherein said means for periodically establishing said magnetic field comprises three electric coils positioned adjacent the outer surface of said chamber to produce overlapping magnetic fields.

5. A pump having means defining a chamber, said means comprising rigid side and end portions, means providing openings in said end portions of said chamber, a flexible member extending through said chamber and passing through said openings, means for sealing the space between said member and said opening, a first fluid carried by said flexible member, a magnetic fluid within said chamber surrounding said member, and means providing overlapping and sequential magnetic fields along the length of said chamber and said flexible member whereby portions of said ferromagnetic material are sequentially acted upon by said magnetic fields to sequentially compress said flexible member and thereby pump said first fluid through said flexible member.

6. A pump as defined by claim **1** wherein said flexible member has a non-circular cross-sectional area.

7. A pump as defined by claim **6** wherein said fluid within said chamber is a ferromagnetic fluid.

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ROBERT M. WALKER, Primary Examiner

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60—54.5; 417—474