March 12, 1968 R. R. NILSON 3,372,644

ELECTROMAGNETIC PUMP HAVING CONCENTRIC ELECTRODES

Filed March 21, 1966

Fig. 1.

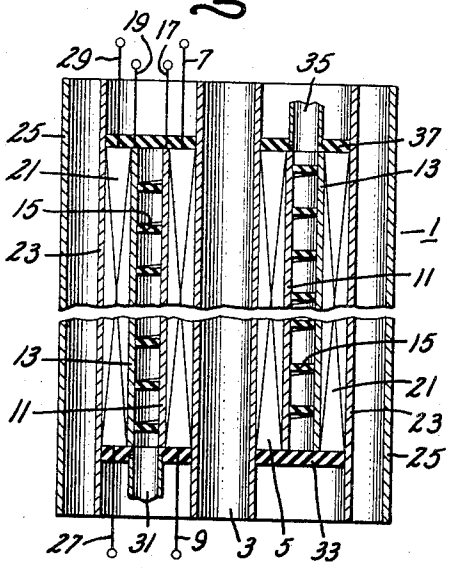


Fig. 3.

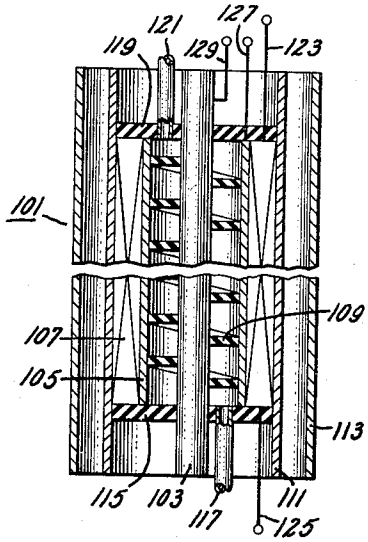


Fig. 4.

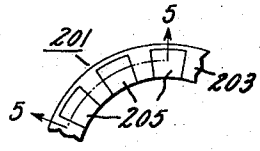


Fig. 2.

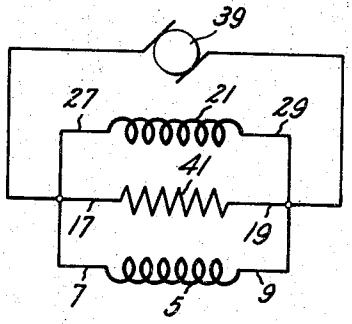
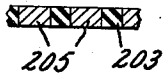


Fig. 5.



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ELECTROMAGNETIC PUMP HAVING CONCENTRIC ELECTRODES

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ABSTRACT OF THE DISCLOSURE

An electromagnetic pump has a pair of cylindrical electrodes defining a cylindrical space therebetween, an insulative spiral deflector mounted in the cylindrical space, a pair of induction coils mounted interiorly and exteriorly of the electrodes, and means connecting the electrodes and the induction coils to an alternating current source.

My invention relates to a novel electromagnetic device which may be used as a pump for conductive liquids or as an ion concentrator.

Electromagnetic pumps for transporting conductive liquid are well known in the art. Such pumps operate by passing an electrical current through the conductive liquid and simultaneously passing a magnetic flux through the liquid at right angles. This then induces motion of the liquid along an axis mutually perpendicular to the direction of electrical current and the direction of magnetic flux.

The practical application of electromagnetic pumps has been largely confined to the pumping of liquid metals. Since liquid metals are in most instances best pumped at elevated temperatures, electromagnetic pumps have not been conventionally provided for the dissipation of heat generated in the pump due to internal resistive power losses. Further, in many instances such pumps have been of rather bulky construction. It is recognized that electromagnetic pumps may be put to uses other than the pumping of liquid metals. For example, electromagnetic pumps may be used to pump and/or concentrate aqueous ionic solutions. In such instances it will be desirable in many applications to provide for cooling of the electromagnetic device to prevent overheating of the ionic solution. Further, it is desirable that the pump be constructed in such a manner that it can be efficiently cooled and still remain compact.

It is an object of my invention to provide a novel electromagnetic pump which may be efficiently employed to pump conductive liquids and/or to concentrate ionic solutions.

It is another object of my invention to provide an electromagnetic pump which is of compact construction.

It is still another object to provide an electromagnetic pump constructed for operation at low temperatures.

These and other objects of my invention are accomplished by providing an electromagnetic pump having first and second concentric electrode means defining a cylindrical space therebetween. An insulative spiral deflector is mounted in the cylindrical space. Means are provided to produce a magnetic flux in the cylindrical space substantially parallel with the electrode means, and means are provided connecting the electrode means and the magnetic flux producing means to an alternating current source.

My invention may be better understood by reference to the following detailed description taken in conjunction with the drawings, in which:

FIGURE 1 is a vertical section of a preferred form of my electromagnetic pump,

FIGURE 2 is a circuit diagram,

FIGURE 3 is a vertical section of an alternate form of my electromagnetic pump,

FIGURE 4 is a detail of a modified deflector, and

FIGURE 5 is a sectioned detail taken along line 5—5 in FIGURE 4.

A preferred embodiment of my invention is shown in FIGURE 1. The pump 1 is provided with a central coolant conduit 3. Surrounding the coolant conduit in heat conductive relation therewith is an induction coil 5. Electrical energy is supplied to the induction coil through leads 7 and 9, schematically shown. An annular electrode 11 is mounted exterior of the induction coil. A larger diameter annular electrode 13 is mounted in spaced relation to the electrode 11. A cylindrical space coaxial with the annular electrodes is thus formed. A spiral deflector 15 is interposed between the inner and outer annular electrodes. As shown the deflector is constructed of insulative material. Electrical leads 17 and 19 are schematically shown attached to the inner and outer annular electrodes, respectively. An outer induction coil 21 is provided exterior of the electrode 13. In thermally conductive relation with the outer induction coil is a conduit 23. A conduit 25 is mounted concentrically spaced from the conduit 23. Electrical leads 27 and 29 are schematically shown attached to the outer induction coil. An inlet conduit 31 is shown attached to an insulative end closure 33 while an outlet conduit 35 is shown attached to an insulative end closure 37.

As illustrated in FIGURE 2 the electromagnetic pump is connected to a source of A-C current 39. For purposes of illustration the induction coils 5 and 21 and the electrodes, represented by resistance 41, are shown connected in parallel. It is immaterial whether the coils and electrodes are connected in series or parallel. It is essential that the coils 5 and 21 be connected so that the magnetic flux lines produced thereby pass in the same direction between the electrodes.

In using the electromagnetic pump 1 a coolant is supplied to the central conduit 3 and to the annulus between the conduits 23 and 25. This provides for heat transfer from the inner and outer induction coils. An ionic solution to be pumped is supplied to the inlet conduit 31. Alternately, a liquid metal or similar conductive fluid could be pumped. The magnetic lines of flux from the induction coils pass longitudinally through the pump in the space between the electrodes. It is noted that a portion of the magnetic flux passes also through the electrodes and other parts of the pump. Only the magnetic flux which passes between the electrodes is utilized, however. To prevent waste of the magnetic flux generated by the induction coils it is preferred that the remaining parts of the pump be manufactured of non-magnetic or paramagnetic materials. For example, if the electrodes were formed of ferromagnetic metal the magnetic flux from the coils would be disproportionately concentrated in the electrodes rather than the space between the electrodes.

As the ionic solution enters the space between the electrodes, the cations and anions present are simultaneously attracted toward opposite electrodes. The magnetic flux acting on the migrating ions will cause a displacement tangentially of the electrodes. Since the electrodes and the induction coils are connected to a source of A-C current, the direction of magnetic flux and the direction of electrical attraction from the electrodes will reverse during each half-cycle. The direction of tangential displacement will remain unchanged and cumulatively displace the ions during each half-cycle. As the ions are tangentially displaced they will contact the deflector 15 and be deflected upwardly toward the outlet conduit 35. Because of physical interactions between the ions and the solvent the solution as a whole will be displaced upwardly toward the outlet conduit 35.

While my device may be used to pump ionic solutions or any other conductive liquid, it may also be used to concentrate ionic solutions. This may be accomplished merely by restraining net displacement of the ionic solution within the pump **1** as by closing a valve, not shown, controlling outlet conduit **35**. This then prevents pumping of the ionic solution as a whole, but leaves the electrical forces acting directly on the ions within the solution unrestrained. The ions are then forced to migrate toward the pump outlet despite physical force interactions with the solvent tending to act as a restraining influence. The concentration of ionic solutions through the interaction of crossed electric and magnetic fields is described, for example, in the "1964 Saline Water Conversion Report," published by the Government Printing Office. A concentrated ionic solution may be obtained merely by allowing net displacement from the outlet conduit at some time after the pump has been placed in operation.

To illustrate the scope of my invention, an alternate electromagnetic pump **101** is illustrated in FIGURE 3. Instead of a central coolant conduit **3**, an electrode **103** which may be either a tube or bar is shown. Spaced from the electrode **103** is an annular electrode **105**. An electrical induction coil **107** is mounted exteriorly of the electrode **105**. A spiral deflector **109** is mounted between the electrodes. An annular conduit **111** is mounted in thermally conductive relation with the induction coil and a second annular conduit **113** is mounted concentrically spaced from the annular conduit **111**. An insulative end closure is provided with an inlet conduit **117** mounted thereon while an insulative end closure **119** is provided with an outlet conduit **121**. Electrical leads **123** and **125** are provided from the induction coil while leads **127** and **129** are provided attached to the electrodes.

The operation of the pump **101** is substantially similar to that of pump **1**. The pump **101** differs in that only one induction coil and coolant conduit is utilized. The coolant conduit surrounding the induction coil may also be omitted, although its use is preferred.

FIGURES 4 and 5 illustrate an alternate deflector construction. A portion of a deflector **201** is illustrated. The deflector includes insulative portions **203** and ferromagnetic inserts **205**. The ferromagnetic inserts tend to concentrate the magnetic flux generated by the induction coil or coils between the electrodes. The insulative portions prevent shorting between the electrodes. It is anticipated that the deflector could be formed of a continuous ferromagnetic spiral having insulation on one surface to prevent shorting of the electrodes. This configuration would, however, suffer a disadvantage in that a portion of the magnetic flux would travel helically through the spiral rather than passing longitudinally between adjacent convolutions of the spiral. It is necessary, of course, that the flux pass longitudinally of the spiral and between convolutions of the spiral in order to be utilized. The use of ferromagnetic inserts strengthens the flux intensity between convolutions.

While I have described my invention with reference to certain preferred forms, it is appreciated that numerous modifications will be readily suggested to those skilled in the art. It is accordingly intended that the scope of my invention be determined with reference to the following claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An electromagnetic pump comprising

first and second cylindrical electrode means defining a cylindrical space therebetween,

an insulative spiral deflector mounted in the cylindrical space,

means producing a magnetic flux in the cylindrical space substantially parallel to said electrode means,

said means producing a magnetic flux including a first induction coil mounted interiorly of said electrode means and a second induction coil mounted exteriorly of said electrode means, and

means connecting said electrode means and said magnetic flux producing means to an alternating current source.

2. An electromagnetic pump according to claim **1** additionally including cooling means mounted adjacent at least one of said induction coils.

3. The combination comprising

a central cooling conduit,

a first induction coil concentrically surrounding said central conduit in thermally conductive relation therewith,

a first annular electrode surrounding said first induction coil and concentric with said central conduit,

a second annular electrode spaced from said first annular electrode and concentric therewith, said first and second annular electrodes defining a cylindrical space therebetween,

a spiral deflector mounted in the cylindrical space,

a second induction coil concentrically surrounding said second annular electrode,

first fluid conduit means for delivering fluid to the cylindrical space between said first and second electrodes, and

second fluid conduit means longitudinally spaced from said first fluid conduit means for receiving fluid from the cylindrical space between said first and second electrodes.

4. The combination according to claim **2** additionally including cooling means exterior of said second induction coil and mounted in thermally conductive relation therewith.

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