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Sept. 24, 1957 N. E. LINDENBLAD 2,807,212

ELECTROMAGNETIC INDUCTION PUMP

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Fig. 1.

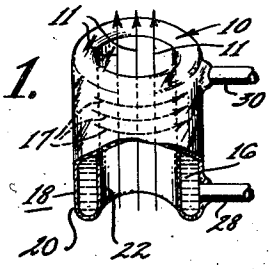


Fig. 2.

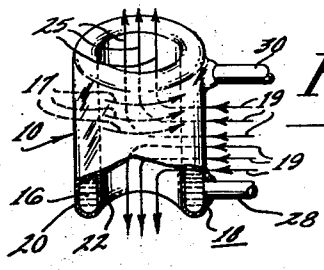


Fig. 3

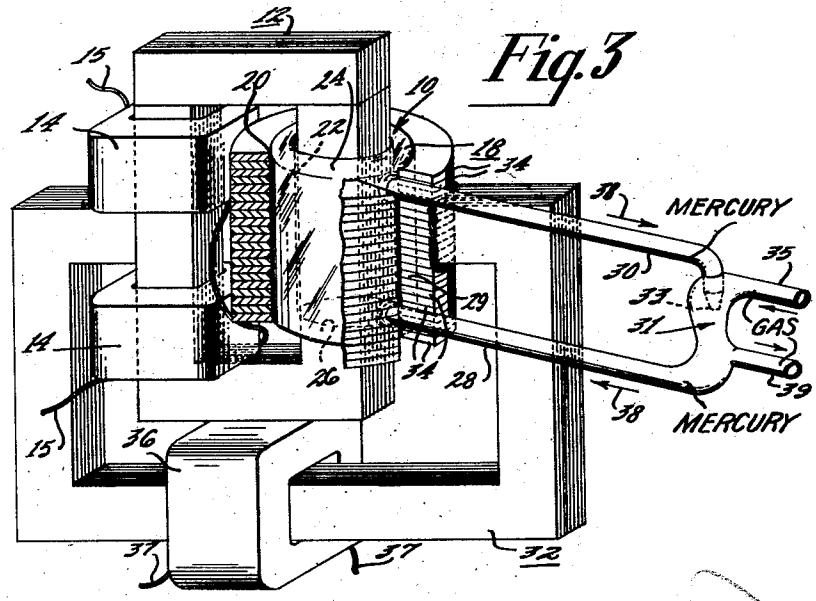
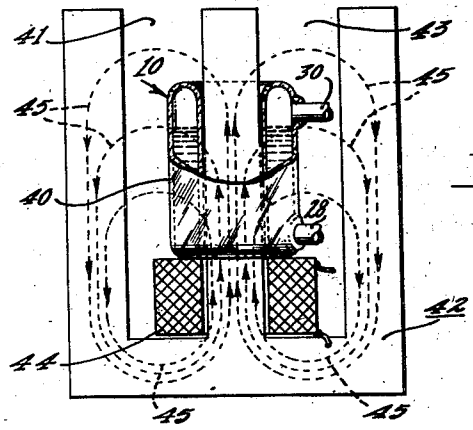


Fig. 4.



INVENTOR.
Nils E. Lindenblad
BY Morris Rebain
ATTORNEY

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Fig. 5.

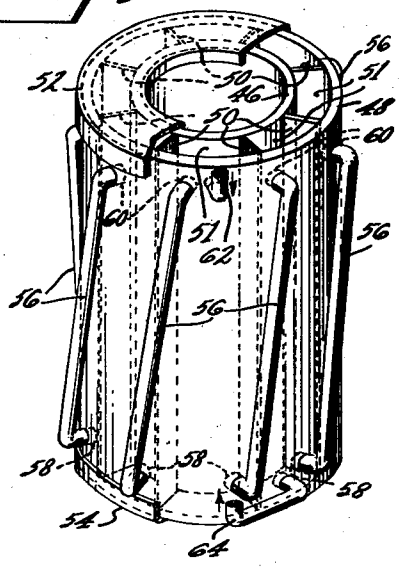


Fig. 6.

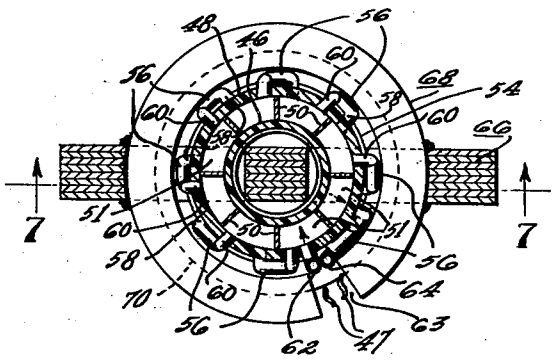
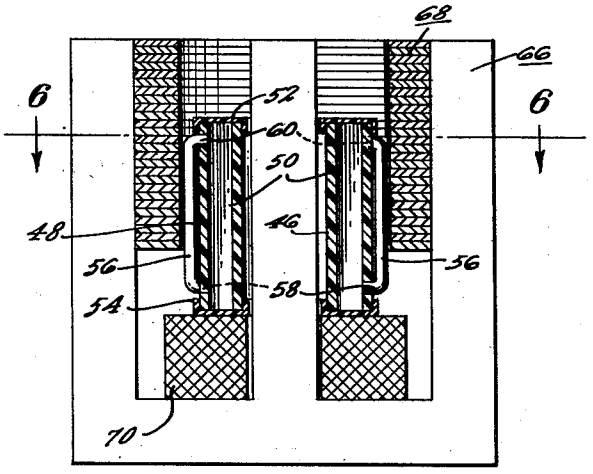


Fig. 7.



INVENTOR.
Nils E. Lindenblad
BY Morris A. Rebai
ATTORNEY

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Fig. 8.

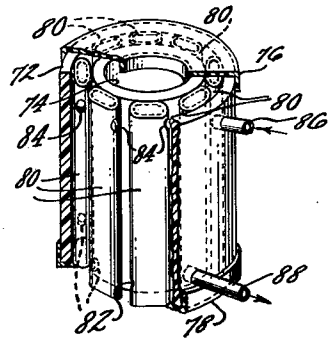


Fig. 9.

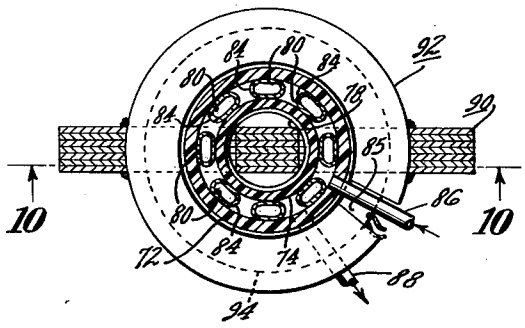
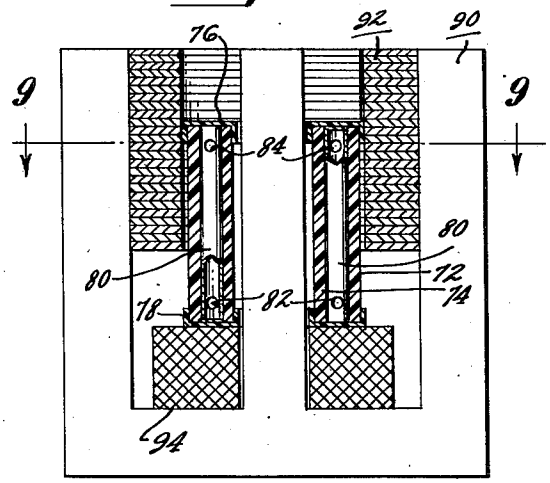


Fig. 10.



INVENTOR.
Nils E. Lindenblad
BY Morris A. Rabin
ATTORNEY

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2,807,212

ELECTROMAGNETIC INDUCTION PUMP

Nils E. Lindenblad, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application December 12, 1952, Serial No. 325,593

8 Claims. (Cl. 103—1)

The invention relates to a device for propelling conductive fluids and particularly, although not necessarily exclusively, to electromagnetic induction pumps which can be made to propel conductive fluids by means of imposing directed forces upon said fluids.

In order to produce a pressure by means of a pump in which no moving parts are necessary or required, it has been suggested to use an electromagnetic force acting perpendicularly to a current induced in a conductive duct or guide through which a conductive fluid material, such for example as gallium, mercury or the like, may be caused to move at will.

It is an object, therefore, of the present invention to provide effective and improved means for exerting directed pressure or force upon a conductive fluid for the purpose of propelling such fluid through associated ducts or guides.

It is also an object of the invention to provide an improved electromagnetic induction pump for propelling a conductive fluid.

It is a still further object of the invention to provide improved means for causing a conductive fluid to be propelled to operate a venturi jet so that the conductive fluid propels other fluids or gases, with which the conductive fluid does not mix.

It is a still further object of the invention to provide an improved electromagnetic induction pump which has no moving parts and in which the directed pressures produced therein are serially additive.

In accordance with the invention, there is provided a main pump body comprising a transformer core. A primary winding is disposed on said core. A container comprising a plurality of insulating concentric cylinders, forming a jacket, is adapted to contain a conductive fluid, for example, mercury. The conductive fluid forms a short-circuited secondary winding. Upon the energization of the primary winding, strong magnetic forces will occur between the primary winding and the secondary winding of the device. Since the container comprising the insulating jacket is fixed, only the conductive fluid can move. The pressure exerted upon the conductive fluid by the magnetic forces will propel the fluid from the inlet section of the device through the insulating jacket to the outlet section of the device. Continuous application of current to the primary winding will thus result in a pumping effect upon the conductive fluid.

The novel features which are considered characteristic of the invention are set forth with particularity in the appended claims, but for a better understanding of the invention itself, both as to its organization and method of operation together with other and further objects and advantages, reference may be had to the following description of certain specified embodiments shown merely for illustration taken in connection with the accompanying drawings, in which:

Figures 1 and 2 are views in perspective and partially in section of an embodiment of a jacket member for use with the present invention;

Figure 3 is a perspective view with certain parts broken away, of a pump constructed in accordance with the present invention adapted to operate a venturi jet so as to propel a gas or other fluid;

Figure 4 is a view in elevation of a modification of the pump of Figure 3;

Figure 5 is a view in perspective with a part thereof cut away to show a section of another embodiment of the jacket member of the present invention;

Figure 6 is a plan view in section of a modification of the pump of Figure 4, including the jacket member of Figure 5, the section being taken along the line 6—6 of Figure 7;

Figure 7 is a view in sectional elevation of the device of Figure 6, the section being taken along the line 7—7 of Figure 6;

Figure 8 is a view in perspective, cut away to show a section of a further embodiment of the jacket member of the invention;

Figure 9 is a plan view in section, the section being taken along the line 9—9 of Figure 10, showing a modification of the pump of Figure 4 and including the jacket member of Figure 8; and

Figure 10 is a sectional view in elevation, the section being taken along the line 10—10 of Figure 9.

Referring now to Figure 3, there is shown a view in perspective of a pump in accordance with the invention. A main pump body or assembly **10** is disposed on a transformer core member **12**. Inasmuch as alternating current operation is inferred, the various windings disposed on the transformer core **12** will be referred to as the primary winding **14** and the secondary winding. The divided primary winding **14** is of conventional design having turn and electrical parameters to conform with the input voltage, current and power demands of the secondary circuit. The secondary winding is formed by the conductive fluid **16** which is or may be contained in a jacket **18**, which is part of the pump body **10**, disposed as aforementioned so as to surround the magnetic core member **12**. The conductive fluid **16** may, for example, be gallium or mercury and is or may be contained in the jacket **18** in order that the fluid may be held in a suitable configuration to make it available as a secondary winding.

The jacket **18** may comprise two concentric insulating cylinders **20** and **22**. Two rings **24** and **26** are disposed at the ends of the cylinders **20** and **22**, respectively, and serve to complete the enclosure of the jacket space. The jacket has an annular cross section. It, therefore, may be described as an annular jacket. An inlet pipe **28** and an outlet pipe **30** connects each end of the jacket space with the rest of the flow circuit to be described.

A second transformer core member **32** carries a linking winding **36** and consists of a series of C-shaped conductive laminations. One leg of the C-shaped laminated member **32** has a series of split-ring shaped laminations disposed thereon so as to form a receptacle into which the jacket **18** may be placed. The split or gap **29** is left to accommodate the inlet and outlet pipes as shown illustratively in Figure 3. The other leg of the laminated core member **32** is joined to the transformer core member **12**.

Upon energization of the primary winding **14** and winding **36**, from a suitable A. C. voltage source (not shown) through terminals **15** and **37**, respectively, peripheral electric currents will be induced to circulate in the conductive fluid **16** contained in the jacket **18** and conforming in shape to the jacket. The magnetic cores have been so arranged that they will perform two functions. In the first instance, referring to Figure 1, the magnetic core **12** allows the axial, magnetic alternating current field, indicated by the arrows **11** (Figure 1), created by the primary current, to pass axially through the conductive fluid cylinder, thus creating a secondary peripherally circulat-

ing current, indicated by the arrows **17**, in the conductive fluid. In the second instance, referring to Figure 2, the magnetic core **32** forms part of a magnetic alternating current circuit which permits a radial magnetic field, indicated by the arrows **19** (Figure 2), to pass through the conductive fluid of cylindrical shape contained in the jacket **18**. A force is thus established between the peripherally circulating current **17** and the radial magnetic field. Since the peripherally circulating current **17** and the radial magnetic field change directions simultaneously, the direction of the established force remains unchanged. The direction of this latter force must be in a direction which is perpendicular to both the peripherally circulating current **17** in the conductive fluid **16** and to the radial magnetic field. This force will therefore, be in an axial direction, as indicated by the arrows **25** (Figure 2), through the jacket **18**. The conductive fluid being the carrier, the peripherally circulating fluid will thus be subjected to the propellant axial force and a flow may be established in the direction of the arrows **38** (Figure 3) through the inlet **28** into the jacket space, to the outlet **30**. The inlet **28** and the outlet **30** are or may be joined to a venturi device **31** of any well known form. The liquid circulated through the jacket **18** is projected into the venturi throat by a nozzle **33**. A fluid, such as a gas to be pumped as stated above, enters a conduit **35** and is forced through an outlet conduit **39**.

In Figure 4, there is shown a view of a simplified and preferred modification of the device of Figure 3. In the particular illustrative embodiment shown in Figure 4 a jacket member **40**, similar in construction to the jacket member **18** previously described, is similarly adapted to contain a conductive fluid which may, for example, be mercury. An E-shaped magnetic laminated core member **42** has a primary winding **44**, energized from a suitable source of A. C. voltage, not shown, surrounding the center leg thereof. The air gaps **41** and **43** between the center leg and the side legs creates leakage, as shown by the leakage lines **45**, in the magnetic field.

As has been pointed out in the discussion in connection with Figure 3, the axial magnetic field through the transformer core **12**, which is established for the purpose of inducing circulating current in the jacket **18**, and the radial magnetic field, which is established for the purpose of completing the electromagnetic interrelations resulting in propellant action, may be derived from independent energizing windings operating on a suitably arranged magnetic path. However, the resultant magnetic field distribution, axially and radially through the conductive fluid in the jacket **18** of Figure 3 from the described symmetrical orderly magnetic core system is the same as if the core were energized at one end thereof and made to have a magnetic leakage while passing through the jacket **18**. The magnetic leakage effective in Figure 4 is created by providing the air gaps **41** and **43** as shown in Figure 4 at the core end beyond the jacket **40** and opposite to the energizing winding **44**. The single winding **44** energized through the terminals **47** can thus be used to obtain the desired effect. A device constructed as shown in Figure 4, has operated and it is believed that operation was obtained in the manner described.

In Figure 5 there is shown a view in perspective of a further illustrative embodiment of a jacket member of the electromagnetic pump in accordance with the present invention. Two concentric insulating cylinders **46** and **48** are fabricated with a series of conductive spoke-like partitions **50** radiating from the inner cylinder **46** to the outer cylinder **48**. Closure members **52** and **54** are disposed at the upper and lower ends, respectively, of the cylinders and are adapted to seal the assembly.

In order to provide a multisection pump in which the pressures are or may be serially additive, a series of externally disposed pipes **56** are arranged peripherally of the outer concentric cylinder **48**. Each one of the pipes **56**, is or may be bent or curved slightly so as to provide means to connect the pipes with a series of inlet openings **58** and a series of outlet openings **60** disposed in the wall of the cylinder **48**. The pipes **56** may, for example, be constructed of some rigid material, for example, stainless steel of low permeability, so as to be non-magnetic, yet still conductive. The interior of each of the pipes **56** may be insulatingly coated or prepared in order that the conductive fluid passing therethrough may be insulated from the pipes themselves. A system inlet duct **62** and an outlet duct **64** have been provided in the assembly for the introduction of the conductive fluid, which, as has been described in connection with the previous figures, functions as the secondary of the electromagnetic pump.

A conductive fluid path is thus provided from the bottom portion of each of the vertical containers **51** through the associated pipe **56** to the top of the next adjacent container. In this fashion the conductive fluid is caused to circulate through the containers **51** in series. The fluid moves in the same direction in each container.

Figure 6 shows a top cross-sectional view of the insulating compartmented assembly of Figure 5. An E-shaped laminated core member **66** similar to the core member **42** of Figure 4, is disposed so that the cylinder **46** surrounds the central leg. A split-ring laminated core member **68** is disposed in contact with the outer arms of the E-shaped core **66**. The compartmented assembly of Figure 5 may thus be disposed over the central arm of the E-shaped core **66**. The inlet pipe **62** and the outlet pipe **64** are disposed adjacent the narrow air gap **63** in the split-ring core member **68**.

Figure 7 is a view in cross section of Figure 6 along the line **7—7** thereof. A primary winding **70** similar to the primary winding of Figure 4 is disposed to surround the central arm of the E-shaped core member **66**. Energization of the primary winding **70** from a suitable source, not shown, will produce a resultant magnetic field distribution axially and radially, through the assembly. Energization of the single winding can thus be used to produce a flow of conductive fluid within the assembly and thus a pressure can be created by means of this flow.

Figure 8 of the drawing is a perspective view of a still further illustrative embodiment of a jacket member of an electromagnetic pump of the present invention. The assembly may comprise two concentric insulating cylinders **72** and **74** having closure members **76** and **78** disposed at the top and bottom thereof respectively, in order to form a unitary assembly. In this modification a plurality of vertically disposed pipes **80** are arranged within the space between the inner and the outer concentric cylinders **72** and **74**, respectively. The pipes **80** are slightly flattened in cross section and each of the pipes **80** has an inlet opening **82** and an outlet opening **84** disposed therein, at the bottom and top thereof, respectively. An external system inlet duct **86** is provided in the outer concentric cylinder **72**. An outlet duct **88** is disposed in the cylinder **72** opposite the aforementioned inlet **86**.

Each of the pipes **80**, which in the illustrative example shown, are made of stainless steel of low permeability, so as to be non-magnetic and yet conductive, have their interior surfaces insulatingly coated. A conductive fluid path is thus provided within the assembly from the inlet duct **86** to the space between the adjacent parallel pipes **80**, into a bottom inlet opening **82**, through a pipe **80** to a top outlet opening **84**, thence into the space between the parallel pipes **80** to another bottom inlet opening **82**, and so on, until a complete circuit has been made around the assembly to the outlet duct **88**.

Figure 9 is a top cross-sectional view showing the insulating compartmented assembly of Figure 8. An E-shaped core member **90** forms a support for the assembly of Figure 8. The assembly is adapted to fit over the central leg of the E-shaped core **90**. A series of metallic laminations in the form of flat split-rings are disposed around the assembly to form a ring shaped core **92**. The inlet and outlet ducts **86** and **88** are adapted to

occupy the space formed by the gap **85** in the core **92**. A Venturi jet, not shown in Figure 9, may be operatively associated with the inlet duct **86** and the outlet duct **88**, as shown in Figure 3, in order to perform the work function, for example, of providing pump action for a refrigerant contained in an external refrigerating apparatus.

Figure 10 is a view of the device of Figure 9 along the line **10—10** thereof. A single primary winding **94** is disposed on the central leg of the E-shaped core **90** for connection to a suitable source of alternating current, not shown. The assembly of Figure 8 is slipped over the central leg of the core **90** and is or may be supported on the primary winding **94**, as shown illustratively in Figure 10. Conductive fluid, for example, mercury, may comprise the secondary winding of the device and may be contained, as before mentioned, in the assembly. Upon energization of the primary winding **94** the conductive fluid is subjected to a propellant axial force and a flow may be established through the duct system into which the assembly space is connected.

The arrangement of the primary coil insofar as the insulating jacket or assembly is concerned, may be altered or changed as convenience or necessity dictates. The primary winding, for example, may be situated above or below the insulating jacket or assembly.

It will thus be apparent to those skilled in the art that a novel electromagnetic pump for use with conductive fluids has thus been described. No conventional moving parts are necessary or required in the device of the present invention. A Venturi jet of conventional type, may be operated with the above described pump in such fashion as to propel other fluids or gases with which the conductive fluid does not mix. Such an electromagnetic pump as herein described may be used for example, to propel a refrigerant at a predetermined stage in a refrigerating cycle.

What is claimed is:

1. An electromagnetic induction pump for propelling a conductive fluid comprising an annular jacket of insulating material, said conductive fluid being disposed within said annular jacket, means for passing an alternating current magnetic field axially through said jacket, means for passing an alternating current magnetic field radially through said jacket, said last-named means comprising an annular pole member disposed adjacent to and encompassing at least a portion of said jacket, and an additional core member included in magnetic circuit with said annular pole member and said first-named means, a fluid inlet pipe disposed upon said jacket, and a fluid outlet pipe disposed upon said jacket at a location longitudinally displaced from said fluid inlet pipe, the interrelation between said fields reacting upon said conductive fluid within said jacket to cause said fluid to be propelled in a direction away from said inlet pipe and towards said outlet pipe.

2. An electromagnetic induction pump for propelling a conductive fluid comprising an annular jacket of insulating material, said conductive fluid being disposed within said annular jacket, a core of magnetic material extending axially through said jacket, a primary winding disposed upon said core, a C-shaped core member of magnetic material having a pair of opposing pole ends, said jacket being disposed between said pole ends with the axis thereof disposed transversely between said ends, an annular pole member for providing radially directed magnetic field in said jacket attached to one of said pole ends, said annular pole member being longitudinally disposed around said jacket, circumferentially disposed about said jacket, said C-shaped member being physically and magnetically joined to said axially extending core of magnetic material, a source of alternating current connected to said primary winding for creating varying magnetic fields in said core, said annular pole member and C-shaped member whereby there are induced related magnetic fields within said conductive fluid, a fluid inlet pipe disposed upon said jacket, and a fluid outlet pipe disposed upon said jacket at a location longitudinally displaced from said fluid inlet pipe, the interrelation between said magnetic fields reacting upon said conductive fluid within said jacket to cause said fluid to be propelled in a direction away from said inlet pipe and towards said outlet pipe.

3. An electromagnetic induction pump for propelling a conductive fluid comprising an annular jacket of insulating material, said conductive fluid being disposed within said annular jacket, an E-shaped transformer core having a central leg, outer legs and an end leg, said jacket being axially disposed about said central leg of said core, an inlet pipe disposed upon said jacket, an outlet pipe disposed upon said jacket in a location longitudinally displaced from said inlet pipe, and a primary winding for generating magnetic lines of force within said transformer core, said primary winding being disposed on said central leg of said core, an annular core member around said jacket, said annular core member being attached to the inner edge of the outer legs of said transformer core, said annular core member extending from the open end of said transformer core to a position spaced from the attached ends of said legs, the passage of said lines of force axially and radially through said fluid within said jacket interrelating to cause said conductive fluid to be propelled within said jacket in a direction away from said inlet pipe and towards said outlet pipe.

4. An electromagnetic induction pump for propelling a conductive fluid comprising an annular jacket of insulating material, said conductive fluid being disposed within said annular jacket, an E-shaped transformer core having a central leg and a pair of outer legs, a primary winding disposed about said central leg adjacent the attached end of said central leg, said jacket being axially disposed about the central leg of said core adjacent the unattached end of said central leg, an inlet pipe disposed upon said jacket, an outlet pipe disposed upon said jacket longitudinally displaced from said inlet pipe in a direction towards the unattached end of said central leg, and a source of alternating current being connected to said primary coil for generating a magnetic field composed of lines of force within said transformer core, an annular core member arranged around said jacket, said annular core member being attached along the inner edge of said outer legs, said annular core member extending from the open end of said transformer core to a position spaced from the attached ends of said legs, said lines of force passing axially through said central leg and leaking radially through said jacket to said annular core to cause said conductive liquid to be propelled through said jacket in a direction away from said inlet pipe towards said outlet pipe.

5. A multisection annular jacket of the type having concentric cylindrical walls for providing serially additive pressure in an electromagnetic induction pump comprising nonmagnetic but conducting partitioning means disposed longitudinally between said concentric walls of said jacket for providing a plurality of longitudinally disposed axial compartments within said jacket, nonmagnetic but conducting conduits connecting an end of each of said axial compartments to the remote end of its adjacent compartment, and an inlet pipe disposed upon one of said axial compartments and an outlet pipe disposed upon another of said compartments.

6. A multisection annular jacket of the type having concentric walls for providing serially additive pressure in an electromagnetic induction pump comprising nonmagnetic but conducting conduits longitudinally disposed between said concentric walls of said jacket and attached thereto, said conduits being spaced to provide between said conduits a plurality of axial compartments within said jacket, said conduits having an aperture at one end thereof connecting the interior of each of said conduits to the adjacent axial compartment on one side thereof,

and said conduits having an aperture adjacent the other end thereof connecting the interior of each of said conduits to the adjacent axial compartment on the other side thereof.

7. An electromagnetic induction pump for propelling a conductive fluid comprising an annular jacket of insulating material, said conductive fluid being disposed within said annular jacket, means for axially passing an alternating current magnetic field having axial and radial components through said jacket, said means comprising a closed loop magnetic core axially threading said jacket, means for providing an alternating magnetic field in said loop core, a split loop magnetic core having two oppositely disposed pole ends, one of said pole ends being arranged circumferentially of the outer wall of said jacket, the other of said ends engaging said first mentioned loop in magnetic contact, and means for providing an alternating magnetic field in said split loop, a fluid inlet pipe disposed upon said jacket, a fluid outlet pipe disposed upon said jacket longitudinally displaced from said fluid inlet pipe, a venturi means having a nozzle and throat, said outlet pipe from said jacket being connected to said venturi nozzle and said inlet pipe from said jacket being connected to said venturi throat, said axial and radial components of said field interrelating within said jacket to cause said fluid within said jacket to be propelled in a direction out of said inlet pipe into said jacket and into said outlet pipe away from said jacket in a continuous flow, said continuous flow providing a means for pumping a second fluid through said venturi.

8. An electromagnetic induction pump for propelling a conductive fluid comprising an annular jacket for containing conductive fluid provided by concentric cylindrical walls of insulating material, said jacket having outlet and inlet ports positioned near opposite ends of the outer one of said walls, means for threading an alternating magnetic field longitudinally through said jacket whereby on circularly flowing alternating current is induced in said fluid, said means comprising a closed loop magnetic core axially threading said jacket, and means for providing an alternating magnetic field in said loop, means for passing an alternating magnetic field radially through said jacket, said means comprising a split loop magnetic core having two oppositely disposed pole ends, one of said pole ends being disposed around a portion of the circumference of said outer wall of said jacket, the other of said ends engaging in magnetic contact said first mentioned loop, means for providing an alternating magnetic field in said split loop, the reaction between said current and said radial magnetic field causing said fluid to be propelled from said inlet port to said outlet port.

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