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Sept. 25, 1956 R. S. BAKER 2,764,095

POLYPHASE ELECTROMAGNETIC INDUCTION PUMP

Filed Feb. 5, 1954 3 Sheets-Sheet 1

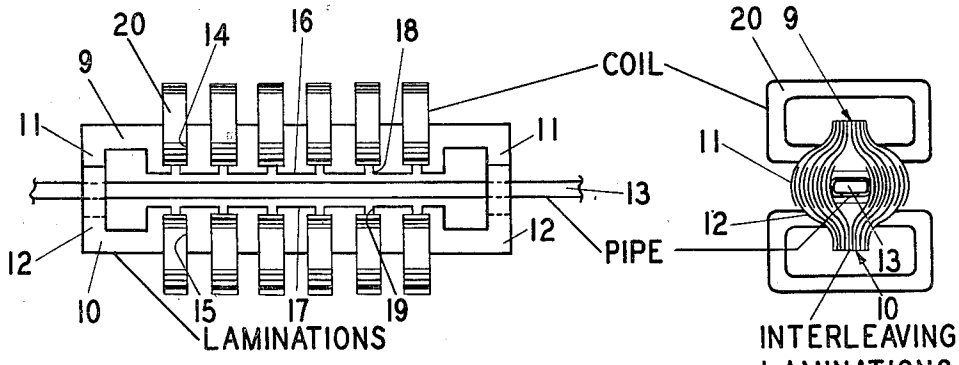


FIG. 1 FIG. 2

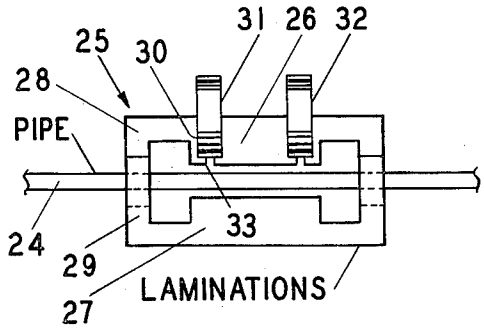


FIG. 3

Richard S. Baker
INVENTOR.
BY Neal J Mosely
his Attorney

POLYPHASE ELECTROMAGNETIC INDUCTION PUMP

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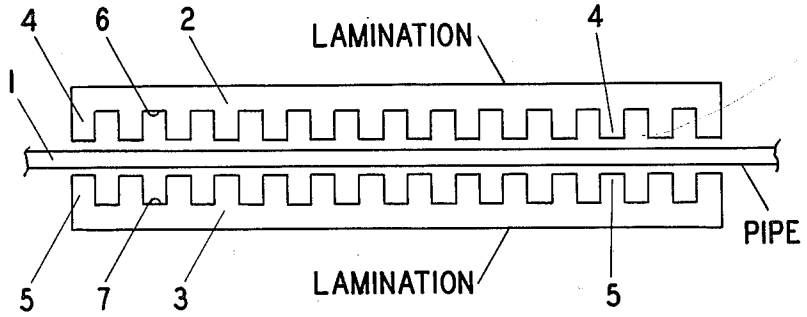


FIG. 7

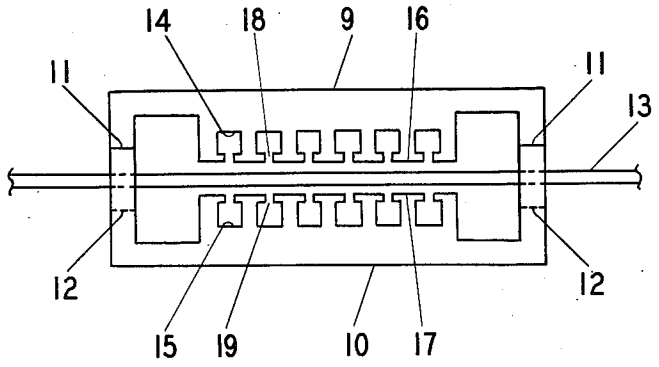


FIG. 4

Richard S. Baker
INVENTOR.
BY Neal J. Mosely
his Attorney

Sept. 25, 1956 R. S. BAKER 2,764,095

POLYPHASE ELECTROMAGNETIC INDUCTION PUMP

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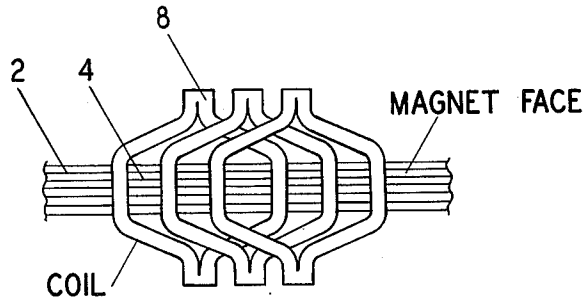


FIG. 8

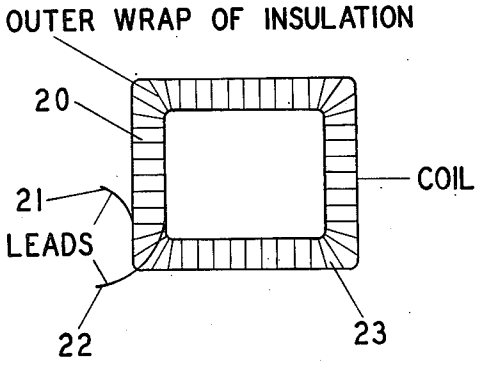


FIG. 5

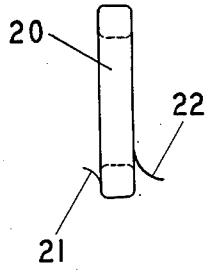


FIG. 6

Richard S. Baker
INVENTOR.

BY Neal J. Mosely
his Attorney

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2,764,095

POLYPHASE ELECTROMAGNETIC INDUCTION PUMP

Richard S. Baker, Butler, Pa., assignor to Mine Safety Appliances Company, Pittsburgh, Pa., a corporation of Pennsylvania

Application February 5, 1954, Serial No. 408,474

9 Claims. (Cl. 103—1)

This invention relates to new and useful improvements in pumps and more particularly to a new and improved electromagnetic induction pump for moving an electrically conductive fluid such as liquid metal, brine, or metal powders.

In the handling of certain fluid materials such as liquid metals, corrosive brines, and certain metal powders it has proved very desirable to have a means for pumping or moving such fluids which does not involve moving parts and therefore avoids certain problems which arise from the necessity of providing seals against leakage of such materials.

One of the solutions which has been proposed for this problem has been the so-called electrical conduction pump. The electrical conduction pump is disclosed in Patent 2,655,107 to Godbold, and Patent 2,386,369 to Thompson. The electrical conduction pump is, in fact, quite old in the art and in its broadest aspects antedates by many years either of the aforementioned patents. This type of pump uses the electromagnetic thrust which is generated by an electric current moving through a conductor transversely to an electromagnetic field. In the conduction pump an electrically conducting fluid is passed through a pipe or conduit which is positioned in a magnetic field. Electrical conductors are connected on opposite sides of the pipe for conducting an electric current through the pipe and through the electrically conductive fluid in the pipe transversely to the magnetic field passing through the pipe. By application of the well known three-finger rule of electro-physics it is apparent that the electrical conductor which is conducting the current transversely to the magnetic field must itself move transversely to the plane defined by the field and the direction of the electric current. Since the electrical conductor in this case is the fluid which is desired to be pumped this electromagnetic thrust is applied to the fluid which is moved accordingly. It is therefore apparent that in this type of electromagnetic pump the electrically conductive fluid in the pipe or conduit is acting as the rotor of a simple electric motor and is being moved by electromagnetic forces impressed upon it. For a number of reasons this type of electrical pump has not proved entirely satisfactory. The principal reason for dissatisfaction with this type of pump is the extremely low efficiency of this pump. It has been found from considerable experience in the manufacture of these pumps that the maximum efficiency attained in a pump having any appreciable capacity is on the order of 2 to 3 per cent.

Another approach which has been made to the problem of moving electrically conducting fluids without the use of pumps having moving parts has been the polyphase electromagnetic induction pump. This type of pump makes use of the principle of the polyphase induction motor. In a pump of this type there are provided a number of field coils which are connected to provide a moving magnetic field which induces an electric current and counterfield in the electrically conducting fluid and drags the fluid along with the field in the same manner as the rotor of the polyphase electric induction motor is moved. Typical patents which disclose this type of electrical induction pump are Patent 1,298,664 to Chubb and Patent 2,099,593 to Bender et al.

It is therefore one object of this invention to provide a polyphase electromagnetic induction pump having a new and improved design.

Another object of this invention is to provide an improved polyphase electromagnetic induction pump having an improved magnetic core construction and an improved arrangement of the magnetic field coils therefor.

Another object of this invention is to provide a polyphase electromagnetic induction pump which is simply constructed and easily assembled of relatively inexpensive materials and which has a substantially greater efficiency than other induction pumps heretofore made .

Other objects of this invention will become apparent from time to time throughout the specification and claims as hereinafter related.

This invention comprises a new and improved construction and combination of parts and their cooperating relation one to another which will be described more fully hereinafter and the novelty of which will be particularly pointed out and distinctly claimed.

In the accompanying drawings to be taken as a part of this specification there are clearly and fully illustrated two preferred embodiments of this invention in which drawings:

Figure 1 is a top view plan of the magnetic core, field coils and fluid conducting pipe for this improved polyphase electromagnetic induction pump,

Figure 2 is an end view of the pump disclosed in Fig. 1 and shows the interleaving end laminations of the magnetic core,

Figure 3 is a top view plan of a pump substantially identical with that shown in Fig. 1 in which the magnetic field coils are positioned on only one side of the magnetic core laminations,

Figure 4 is a view in side elevation of the fluid conducting conduit and magnetic core laminations of the pump shown in Fig. 1,

Figures 5 and 6 are front and side elevations respectively of the field coil for the pump shown in Fig. 1,

Figure 7 is a view of the fluid conducting conduit or pipe and the magnetic core laminations for a prior art type of induction pump, and

Figure 8 is a bottom plan view facing the magnetic core laminations of the pump shown in Fig. 7 showing the field coil connections for a typical prior art type of polyphase electromagnetic induction pump.

Referring to the drawings by numerals of reference and more particularly to Figs. 7 and 8 there is shown a prior art type of electromagnetic polyphase induction pump. In Fig. 7 there is shown the pipe or conduit 1 which conducts an electrically conductive fluid which is moved by this pump. The pipe 1 has laminated field electromagnets 2 and 3 spaced on opposite sides thereof. The field magnets 2 and 3 have a plurality of teeth 4 and 5 which extend toward the pipe 1 and are provided with a plurality of slots 6 and 7 for receiving the windings of the electromagnetic field coils. In this type of pump the slots 6 and 7 are usually provided with magnetic field windings which are coils 8 placed so that two sides of each coil lie in slots in the magnet face. This is the standard method of winding the stators of ordinary commercial polyphase induction motors and is shown in Fig. 8. In operation this type of pump construction provides a traveling magnetic field across the air gap between teeth 4 and 5 of the laminated magnetic core and

moving linearly of the pump and drags the electrically conductive liquid or fluid in the pipe or conduit **1** along with the field in the same manner as the rotor of a polyphase induction motor.

The use of a pump of the design just described has many advantages over the standard conduction type pump, particularly in higher efficiencies which are obtainable in larger pump sizes. The use of this type of pump, however, also produces many undesirable effects due to its rather inefficient design both in the construction of the magnetic core laminations and in the arrangement of the magnetic field coils. One of the undesirable effects which is produced by this type of pump is the loss of power as heat in the pipe walls and in the fluid which is being pumped. A large part of this power loss occurs at each end of the pump where the pipe and the electrically conductive fluid are exposed to the end magnetic field which is an alternating field and does not move linearly of the pump from tooth to tooth as does the remainder of the field. While the overall effect of the plurality of field windings around the several magnetic cores is to produce a magnetic field which moves along the length of the pump from tooth to tooth the magnetic field at each end of the pump between the end teeth is mainly stationary in space. This magnetic field thus alternates with time at line frequency. The result of this type of construction is that with the open end type laminations as shown in Fig. 7 as is used in previously constructed induction pumps the magnetic field at each end of the pump produces a relatively large power loss in the form of heat which is generated in any conductor exposed to the magnetic field. Another undesirable effect which is produced in this type of pump is the unbalance of line currents that results from the unequal magnetic field conditions existing along the magnet. This unbalance of line currents carries back to the power source and causes an excessive heating of the electrical apparatus which is used to supply the pump. The most pronounced of these undesirable effects however is the loss of pumping force or loss of thrust upon the liquid being pumped which results from the unsymmetrical magnetic field conditions that exist along the air gap between the magnet faces. In the ordinary three-phase induction motor the magnetic field produced by the line currents in the stator winding consists mainly of a traveling field that travels from point to point around the air gap surface of the stator and causes the rotor to follow. The turning motion of the rotor is transmitted to the shaft upon which the rotor is mounted and the shaft in turn transmits the mechanical power thus developed to other apparatus. Because the stator of an ordinary three-phase induction motor is circular the magnetic field conditions around the air gap are symmetrical. This symmetrical field relationship produces an efficient operation of an induction motor. This arrangement however is not practical for polyphase electromagnetic induction pumps due to the necessity of providing an opening in the magnetic field for the passage of the pipe or conduit through which the liquid or other fluid flows.

In a similar manner there are certain distinctly undesirable effects which result from the conventional coil winding used in polyphase induction pumps as is shown in Fig. 8. Most of these undesirable effects produce certain electrical unbalances and magnetic field unbalances which result in a low pump efficiency. One of the undesirable effects which is produced by this type of winding (in which the coils are placed so that two sides of each coil lie in separate slots in the magnetic laminations spaced according to the number of phases of the electric current used) is an unbalance of the line currents which carries back to the power source and causes heating of the electrical apparatus used to supply the pump. Another undesirable effect which is produced by this type of coil winding is the necessity of using a double layer winding which causes the pump to be excessively long and

with a resulting excessive loss of heat by thermal radiation and conduction in the liquid being pumped. Another undesirable effect which is produced by this type of electrical winding and perhaps the most pronounced of these undesirable effects is the loss of pumping force or thrust upon the fluid being pumped which results from the unsymmetrical magnetic field conditions that exist along the air gap between the magnet faces of the field core. These unsymmetrical magnetic field conditions are produced both by the type of field core laminations which are used and also by the fact that the field coil is positioned in two different slots and is subjected to different field conditions at two different points.

I have found by test and observation that certain improvements in the construction of the laminations for the magnetic field core and certain improvements in the construction of the magnetic field coils will result in substantial increases in the efficiency of an electromagnetic induction pump and will also diminish the undesirable line current effects referred to above. These improvements in the construction of the polyphase electromagnetic induction pump and more particularly in the construction of the field core laminations and the field coils constitute important features of my invention and are shown more clearly in Figs. 1, 2, 4, 5 and 6. In Fig. 4 there is shown a view of the field core laminations in the form to which I have modified them to correct for some of the undesirable effects of the lamination construction shown in Fig. 7. In this view the upper and lower sets of core laminations are referred to by the reference numerals **9** and **10** and are constructed with end sections **11** and **12** respectively which project slightly beyond the pole faces of the magnetic laminations and are arranged to be interwoven so as to provide a continuous flux path for the magnetic field at each end of the pump. The end portions **11** and **12** of the magnetic core laminations are bent outward a sufficient amount to allow the pipe or conduit **13** to pass through the laminations and to pass between the magnetic pole faces of the pump. As in the case of the laminations shown in Fig. 7 these modified laminations shown in Fig. 4 are also provided with slots **14** and **15** which receive the magnetic field coils. The slots **14** and **15** in the laminations **9** and **10** are of a shape which provides T-shaped magnetic teeth **16** and **17**. The T-shaped teeth **16** and **17** have relatively small clearances as indicated at **18** and **19** which provide for an improved operation of the pump in a manner which will be hereinafter described. When the laminations are arranged in the manner shown in Fig. 4 and wound with suitable field coils the magnetic field produced by the winding in the slots **14** and **15** crosses the air gap between the slotted surfaces or pole faces of the laminations **9** and **10**. As the magnetic field crosses the air gap between adjacent pole faces there is an effective movement of the magnetic field which will produce motion in the desired direction in the fluid in the pipe or conduit **13**. The laminations **9** and **10** can be stacked to any suitable thickness as determined by the size of the pipe or conduit **13**. As the ends **11** and **12** of the laminations overlap, the return paths for the magnetic field set up by the coil windings are kept from passing through the pipe and electrically conductive fluid therein as was the case in the lamination construction shown in Fig. 7. The amount of power lost in the form of heat in the pipe and electrically conductive fluid is therefore reduced substantially. It should also be noted that with this type of construction the coil currents are all brought to substantially the same value and are held more nearly in balance thereby enhancing the commercial acceptability of this type of pump.

I have also found by test and observation that certain modifications of the field coil construction in the polyphase electromagnetic induction pump results in more efficient operation thereof. The type of field coil which I propose to use in my pump is shown in front and side

view respectively in Figs. 5 and 6. This coil is referred to generally by the reference numeral **20** and is provided with electrical leads **21** and **22** and an outer insulating wrap **23**. This type of coil is a single continuous loop coil and is arranged to have only one side of the coil positioned in one of the slots **14** or **15** of the field core laminations. The use of this type of coil construction has provided a greatly increased efficiency in this type of pump in a manner which will be more completely described in connection with the operation of the pump. In Figs. 1 and 2 the laminations which are shown in Fig. 4 and the field coil which is shown in Figs. 5 and 6 are shown in an assembled position. The reference numerals used in Figs. 1 and 2 are the same as those used in Figs. 4, 5 and 6. In Figs. 1 and 2 there are shown top and end views respectively of the assembled pump construction using the laminations shown in Fig. 4 and the coil construction shown in Figs. 5 and 6. In this assembled pump the laminations are positioned on opposite sides of the pipe or conduit **13** in substantially the same manner as is shown in Fig. 4 with the teeth faces **16** and **17** positioned to provide a minimum air gap across the pipe. The end portions **11** and **12** of the laminations **9** and **10** are interleaved to provide a return path for the magnetic flux. This construction is shown more clearly in the end view in Fig. 2. The field coils **20**, each of which comprises a loop-type coil, are positioned in the slots **14** and **15** along the length of the field core laminations **9** and **10**. The pump is preferably provided with coils in an integral multiple of the number of phases of the electric current used to operate the pump. Thus, this pump being arranged for operation on a three-phase circuit is provided with six pairs of field coils. In using this type of field coil the coil passes through only one of the slots and is thus required to meet the conditions of the magnetic field at only one location instead of two locations as in the case of the type of coil winding shown in Fig. 8. With this type of coil, because of the fact that the coil is not required to be fitted in two different slots, it is possible to shorten the length of the magnetic structure materially and thereby saving material and reducing the radiant heat losses from the surfaces of the pumping section. In using this type of coil it should be noted that opposed pairs of coils in the same phase relation may be connected in series or in parallel as desired. It should also be noted that more than one slot per phase per magnetic pole can be used to provide a more nearly continuous change in flux values linearly of the pump. The coils may also be varied in size according to space and insulation requirements from a fraction of a turn per coil to many turns per coil. Where several adjacent slots are used for a single phase a single coil may be wound with successive turns in each of said several adjacent slots.

The operation of this type of pump is substantially the same as that described for the prior art type of pump having the construction shown in Figs. 7 and 8. The principal differences in this type of pump lie in the increased efficiencies and lower line losses which are produced in this pump as compared to the aforementioned prior art type of pump. The field coils **20** of the pump shown in Fig. 1 are preferably connected in pairs across a three-phase electric circuit with successive pairs of coils connected to different phases of the circuit. Thus, looking at the six coils of the pump shown in Fig. 1 from left to right the first pair of coils would be connected across the first phase of a three-phase circuit. The second pair of coils would be connected across the second phase and the third coils across the third phase. The fourth, fifth and sixth coils would be connected across the first, second and third phases, respectively. This arrangement will provide a traveling magnetic field extending across the air gap, pipe and fluid between opposed lamination teeth and moving along the length of the magnetic core laminations from tooth to tooth thereof thereby dragging along the electrically conductive fluid in the pipe or conduit **13** in the same manner as does the rotor in the polyphase induction motor.

To illustrate some of the advantages attained by this type of construction some figures will be set forth comparing the efficiencies of this pump and the prior art type pump as disclosed in Figs. 7 and 8. The efficiencies of this type of pump are extremely low for the small capacity (40 gal./min) pumps which were tested and so the differences in percentages of efficiency may appear rather small but they are rather large increases in efficiency when considered in proportion to the efficiencies dealt with. When the prior art type of pump as described in connection with Figs. 7 and 8 is connected for operation it is found that due to the open ends of the magnetic core laminations the induced currents caused by the alternating magnetic flux across the end of the pump result in line currents which are unbalanced to the extent of 100% and also results in a 50% unbalance of currents in the coils for the end coils of the pump. This degree of unbalance caused by the open ended lamination construction was approximately the same whether the improved coil shown in Figs. 5 and 6 was used or the older coil construction shown in Fig. 8. When the lamination construction shown in Fig. 4 was used for the same type of pump and with the coils shown in Figs. 5 and 6 the coil currents were found to be in balance for all of the field coils and the line currents were found to be unbalanced only to the extent of about 20%. When the lamination construction shown in Fig. 4 was used with the coil construction shown in Figs. 5 and 6 (that is the assembled pump construction shown in Figs. 1 and 2) an overall efficiency of about 6% was obtained for the pump. When this same pump construction was used with the coil windings shown in Fig. 8 replacing the coil windings shown in Fig. 1 the efficiency of the pump decreased to 1.1%. Another element of construction of this pump which has resulted in increased efficiency is the closed slot for the coils which is produced by the T-shaped magnetic teeth faces **16** and **17** of the laminations **9** and **10** as shown in Fig. 4. This construction appears to produce a more balanced magnetic field and results in material increase in efficiency of the pump. This type of construction was tested on both the open ended type laminations shown in Fig. 7 and the closed ended type laminations shown in Fig. 4 and in both cases resulted in an increase of efficiency on the order of 70% over the pumps using the open slotted laminations as shown in Fig. 7.

In Fig. 3 there is shown a slight modification of the construction shown in Figs. 1 and 2 in which there is provided an arrangement for operating a pump of this general type with only two coils positioned on one side of the lamination and arranged for operation on a two-phase electric circuit. The pump shown in Fig. 3 is generally designated **25** and has a pipe or conduit **24** extending therethrough for conducting an electrically conductive fluid for movement by the magnetic field of the pump. The pump **25** is provided with two sets of magnetic field core laminations **26** and **27** positioned on opposite sides of the conduit **24**. The field core laminations **26** and **27** have spaced end sections **28** and **29** which are arranged in overlapping relation in the same manner as the end sections **11** and **12** of the field core laminations **9** and **10** in the pump shown in Fig. 1. The upper field core laminations **28** are provided with a pair of slots **30** which receive field magnetic coils **31** and **32**. The slots **30** are of a shape substantially the same as the slots **14** and **15** for the magnetic core laminations shown in Fig. 1 and provide magnetic teeth having a narrow air gap **33** which arrangement is substantially the same as that shown in Fig. 1. The field coils **31** and **32** are a single loop type of coil which is substantially the same as the coils **20** for the pump shown in Fig. 1. The coils **31** and **32** are connected across a two-phase electric circuit and are operable to produce a traveling magnetic field moving linearly of the pump, which field is operable to move the electrically conductive

fluid in the pipe or conduit **24**. With the closed end sections on the magnetic core laminations and the single loop type of coil the pump shown in Fig. 3 is a relatively efficient pump even though its coils are located on only one side of the field core laminations. It should be understood however that coils similar to the field coils **31** and **32** could be positioned on the lamination **29** in the same manner as said coils are positioned on the lamination **28** and such an arrangement would produce a slightly more efficient pump. A pump having all of its coils located on one side of the magnetic core laminations would be particularly useful in certain installations where space requirements would not permit large coils projecting from both sides of the pump.

Although there have been described in this specification only two embodiments of this invention it will be obvious to those skilled in the art that other embodiments of this invention are possible without departing from the scope and intent of coverage of this patent which should be limited only by the appended claims.

Having thus described my invention, what I desire to claim and secure by Letters Patent is:

1. In an electromagnetic induction pump, a conduit for conducting an electrically conductive fluid, magnetic field cores positioned on opposite sides of said conduit, at least one of said field cores having a plurality of slots providing spaced magnetic teeth extending linearly of said conduit, electrical coils wound on said field core in said slots and connected to energize said magnetic teeth sequentially to produce a traveling magnetic field extending from said one field core to the other core through said conduit and moving linearly of said conduit, and said field cores being arranged with end connections providing a magnetic flux path completing the magnetic flux circuit at each end of said pump.

2. In an electromagnetic induction pump, a conduit for conducting an electrically conductive fluid, laminated magnetic field cores positioned on opposite sides of said conduit, at least one of said magnetic field cores having a plurality of slots providing spaced magnetic teeth extending linearly of said conduit, electrical coils wound on said field core in said slots and connected to energize said magnetic teeth sequentially to produce a traveling magnetic field extending through said conduit from one field core to the other field core and moving linearly of said conduit, and said magnetic field core laminations being arranged with overlapping end laminations extending across said conduit and providing a magnetic flux path to complete the magnetic flux circuit at each end of said pump.

3. A pump as defined in claim 2 in which the field cores are each provided with energizing coils arranged for connection in a polyphase electric circuit and the number of coils is an integral multiple of the number of electric phases.

4. A pump as defined in claim 3 in which the coil slots are shaped so that the magnetic teeth faces are substantially wider than the base portions of the magnetic teeth thus providing a relatively narrow air gap between adjacent magnetic tooth faces.

5. In an electromagnetic induction pump, a conduit for conducting an electrically conductive fluid, magnetic field cores positioned on opposite sides of said conduit and having end connections providing a magnetic flux path completing the magnetic flux circuit at each end of said pump, at least one of said field cores having a plurality of slots providing spaced magnetic teeth extending linearly of said conduit, separate electrical coils wound on said field core one in each of said slots and each coil being wound in only one of said slots, and said coils being connected in an electric circuit to produce a traveling magnetic field extending through said conduit from one field core to the other field core and moving linearly of said conduit.

6. A pump as defined in claim 5 in which the magnetic field cores are of a laminated construction and in which the end laminations are arranged in overlapping relation providing an end connection extending across said conduit between said field cores.

7. A pump as defined in claim 6 in which the field cores are each provided with energizing coils arranged for connection in a polyphase electric circuit and the number of coils is an integral multiple of the number of electric phases.

8. A pump as defined in claim 6 in which the coil slots are shaped so that the magnetic teeth faces are substantially wider than the base portions of the magnetic teeth thus providing a relatively narrow air gap between adjacent magnetic teeth faces.

9. In an electromagnetic induction pump, a non magnetic conduit for conducting an electrically conductive fluid, a pair of electromagnetic field cores positioned on opposite sides of said conduit and in close proximity thereto, said field cores each being of a laminated iron construction and having slots therein providing magnetic teeth spaced linearly of said conduit and alined one for one, each of said field core laminations having projecting portions at each end extending past said conduit and overlapping the projecting laminations of the other field core to provide closed flux paths at each end of the pump, said slots being shaped to provide teeth faces substantially wider than the base portions of the magnetic teeth and relatively narrow air gaps between adjacent teeth, separate field energizing coils wound one in each of said slots, said coils being continuous loop coils having only one side of each coil connected in only one of said slots, said coils being arranged for connection in a polyphase electric circuit and being in number an integral multiple of the number of phases in the circuit, and said coils when connected for energization in a polyphase circuit being operable to produce a traveling magnetic field extending through said conduit from one field core to the other field core and moving linearly of said conduit in one direction only and operable to move said electrically conductive fluid in said one direction.

References Cited in the file of this patent

UNITED STATES PATENTS

2,397,785	Friedlander	Apr. 2, 1946

FOREIGN PATENTS

344,881	Great Britain	Mar. 3, 1931
543,214	Germany	Feb. 3, 1932