# United States Patent [19]

**Ertaud et al.**

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[54] **LIQUID METAL CONDUCTION PUMP**


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[51] **Int. Cl.** ..... **H02n 4/20**

[58] **Field of Search** ..... 417/50



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[57] **ABSTRACT**

A conduction pump having a simple structure for liquid metal, comprising a coil constituted by a refractory casing containing liquid metal and a metal flow duct connnected to the casing by two end pieces each comprising at least one opening.


**10 Claims, 5 Drawing Figures**

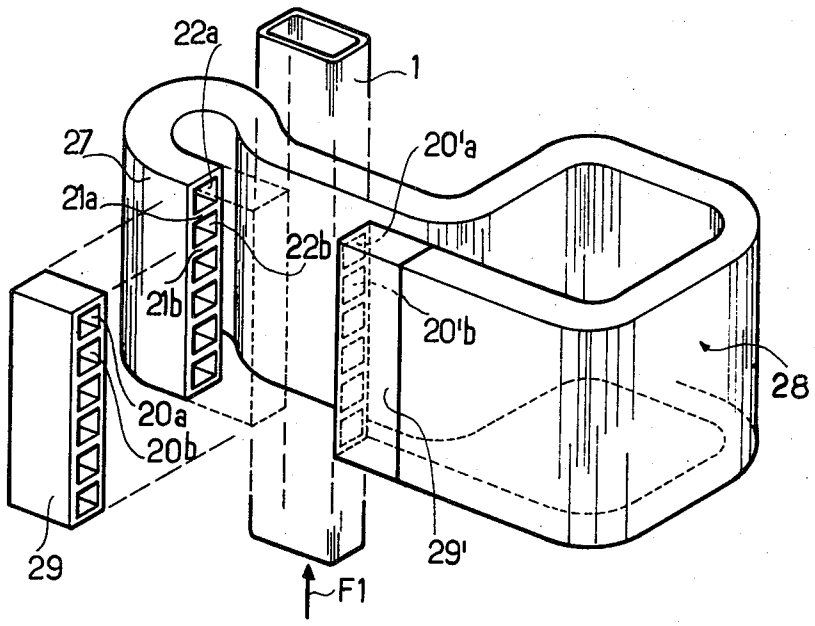

FIG.1

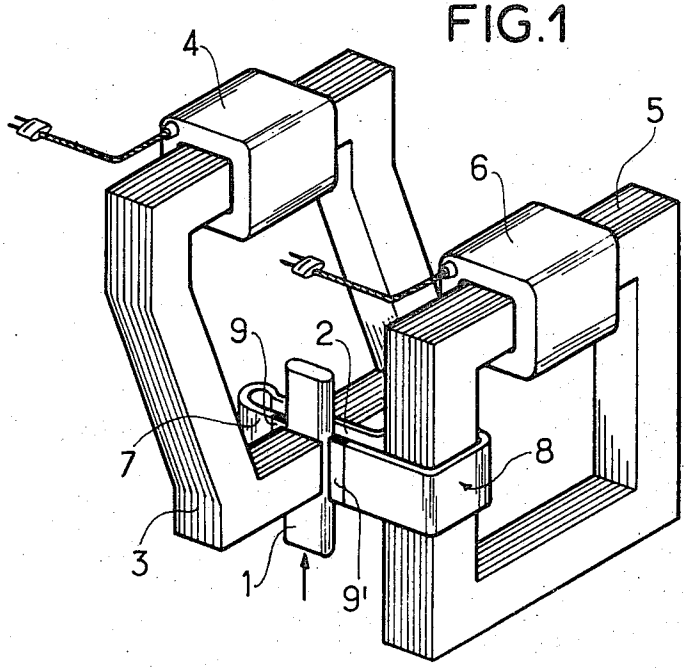


FIG.2

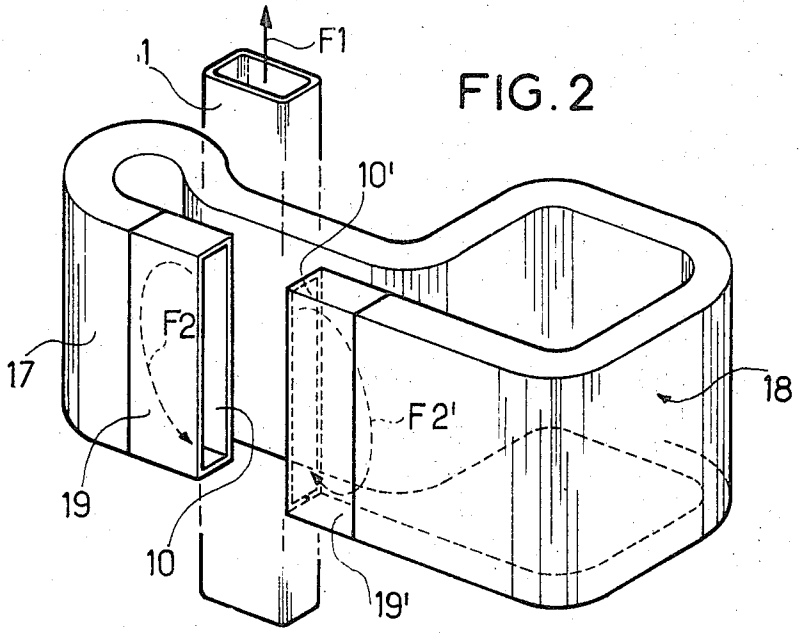

FIG.3

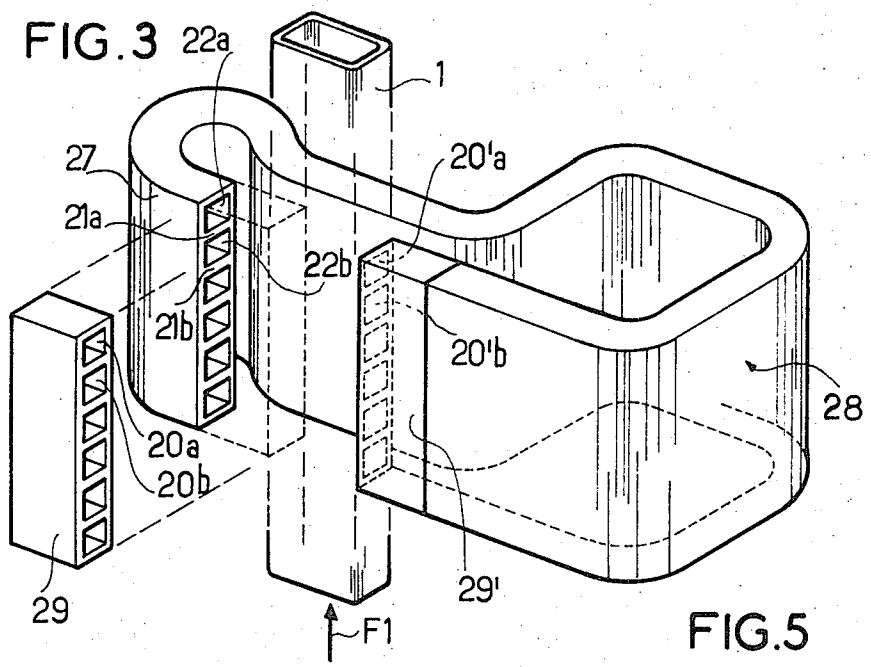


FIG.5

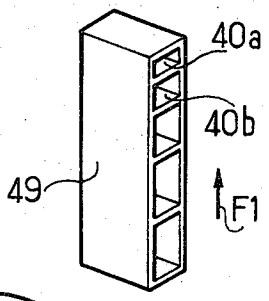


FIG.4

# LIQUID METAL CONDUCTION PUMP

The present invention concerns a conduction pump having a simple structure for liquid metal, which may be immersed in the said metal.

It is known that conduction pump designates a pump in which the liquid metal is set in motion by the electromagnetic force produced by the combined action of a magnetic induction and an electric current flowing perpendicular to the magnetic field, across a section of liquid metal flux.

A pump of that type is the object of French Pat. No. 71,09,159 filed in the name of the Applicant on Mar. 16, 1971.

According to an embodiment described in the above mentioned patent, the pump comprises:

A first magnetic circuit provided at its upper part with a first feed winding, and at its lower part with an air gap in which a horizontal magnetic field is set up;

A rectilinear duct having a vertical axis crossing the said air gap, used for the liquid metal flow;

A coil, whose middle plane is horizontal, constituted by a refractory casing containing liquid metal in electrical contact at the level of the said air gap with the liquid metal flowing in the said duct;

A second magnetic circuit provided, at its upper part, with a supply winding inducing an electric current in the coil, the direction of that current being horizontal and orthogonal to the magnetic field in the section of liquid metal situated in the said air gap.

In that pump, the coil is arranged appreciably below the said first and second windings, this enabling the said windings to be above the liquid metal bath when the coil is immersed in that bath.

The refractory casing of the coil is connected to the duct by means of two rigid electrodes ensuring electrical continuity between the liquid metal contained in the refractory casing and the metal flux flowing in the duct.

Pumps of the type described in the aforementioned patent give absolute satisfaction, but the Applicant has attempted to make pumps having a simplified structure and nevertheless having acceptable efficiency, which may be used, for example, in applications where they are called upon to operate on a discontinuous basis.

To obtain the pump according to the invention which is the object of the present application, the Applicant conceived the idea of replacing the rigid-electrodes, which were delicate and expensive to manufacture in the liquid coil pump in the aforementioned patent, by end pieces provided with at least one opening establishing a communication between the inside of the refractory casing of the coil and the inside of the duct.

Pumps whose coils end in end pieces provided with openings have acceptable effeciency and have given satisfaction. In particular, the filling of the coil with liquid metal on starting up the pump, as well as the discharging of that metal after the stopping of the pump are considerably simplified. Indeed, on starting up the pump, the coil is immersed in a liquid metal bath and filled with that same metal. Moreover, the Applicant has observed that it was possible to improve that output in a simple way by cancelling an interference flow of metal which originated in an opposite direction to that of the metal flow in the duct.



According to a first variant of the invention, the end pieces are provided with n openings extended by separations dividing the coil and end pieces into n parallel channels.

According to a second variant of the invention, the end pieces are provided with n openings extended by separations dividing only the end pieces into n parallel channels.

The following description with reference to the accompanying drawings will make it easier to understand how the invention may be implemented.

FIG. 1 is a general view of a pump according to the invention.

FIG. 2 shows diagrammatically a conductive coil provided with end pieces according to the invention.

FIG. 3 is a first variant of a coil provided with end pieces.

FIG. 4 is a second variant of a coil provided with end pieces.

FIG. 5 shows diagrammatically a particular end piece.

The electromagnetic conduction pump such as that shown in FIG. 1 comprises a vertical duct 1 for the liquid metal flow, preferably made of refractory material crossing the air gap 2 of a first magnetic circuit in the shape of a frame 3.

That frame is connected with a winding 4 situated at the upper part of the frame 3 and wound round one of the sides of that frame. The winding 4 is fed with alternating current, so as to set up, in the section of liquid metal situated in the air gap 2, a horizontal magnetic field. That air gap is situated at the lower part of the frame 3.

The pump comprises, moreover, a second magnetic circuit in the shape of a frame 5, a feed winding 6 situated in the upper part of the frame 5 and wound round one of the sides of that frame, and a conductive coil 7 having a rectangular cross-section surrounding one of the vertical sides of the frame 5.

The winding 6 is fed with alternating current so as to induce an alternating current in the conductive coil 7. That coil 7 whose middle plane is horizontal is constitued by a refractory casing 8 containing liquid metal. That casing 8 is connected to the duct 1 by two end pieces 9, 9′ each comprising an opening making the inside of the casing 8 communicate with the inside of the duct 1, so that metal may flow between the casing 8 and the duct 1. The section of metal situated between the end pieces 9, 9′ has the alternating current generated in the coil 7 passing through it.

The coil 7 is arranged so that the direct current flowing between the end pieces 9 and 9′ be orthogonal to the magnetic field set up in the air gap 2 and to the axis of the duct 1. The end pieces 9 and 9′ are situated on either side of the part of the duct 1 arranged in the air gap 2, and the casing 8 comprises a plane part situated facing that part of the duct arranged in the air gap 2, also arranged in the air gap 2. The spire 7 is arranged at an appreciably lower level than the windings 4 and 6, so that these windings 4 and 6 be situated appreciably above the liquid metal bath when the coil 7, as well as the part of the duct 1 situated below that coil are immersed in the metal bath. It is thus possible, to protect the said windings 4 and 6 against any accidental rise in temperature which would make good operation of the pump impossible.

For the vertical electromagnetic force which is then set up in the section of metal situated between the end pieces **9** and **9'** to remain always ascending, it is necessary to ensure that the current and the magnetic field be approximately in phase.

FIG. **2** shows diagrammatically a conductive coil **17**, constituted by a casing **18** containing liquid metal. That coil has a rectangular cross-section and is connected to the duct **1** by two end pieces **19** and **19'** each provided with a rectangular opening **10** and **10'**.

When the pump is in operation, the metal flux in the duct **1** has an ascending direction (vertical arrow F1). Nevertheless, as the Applicant has observed, an interference flow takes place from top to bottom of the liquid in the end pieces **19** and **19'** (arrows F2 and F2'). To cancel that interference flow, which decreases efficiency, end pieces having several openings are manufactured.

FIG. **3** is a first variant of a coil **27** constituted by a casing **28** containing liquid metal and ended by two end pieces **29** and **29'** connecting that coil **27** to the flow channel **1.**

The end piece **29** comprises n openings of equal cross-section, arranged one below another, such as **20***a*, **20***b* . . . Likewise, the end piece **29'** comprises *n* openings having an equal surface, such as **20***a*, **20***b* . . . The openings **20***a*, **20***b* . . . . **20'***a*, **20'***b* . . . , of the end pieces are extended by horizontal partitions such as **21'***a*, **21***t* . . . , situated inside the end pieces and the coil **27.** These partitions separate that coil and these end pieces into n parallel channels **22***a*, **22***b* . . . and they are constituted by insulating or conductive refractory materials, they prevent any interference flow of the liquid metal from top to bottom in the end pieces **29** and **29'** and in the coil **27.**

FIG. **4** is a second variant of the conductive coil **37** whose casing **38** is connected to the duct **1** by two end pieces **39** and **39'**. Each end piece **39, 39'** comprises *n* equal openings, situated one below another, such as **30***a*, **30***b* . . . and **30'***a*, **30'***b* . . . These openings are extended over the length of the end pieces only by horizontal partitions **31***a*, **31***b* . . . and **31'***a*, **31'***b* . . . dividing the end pieces into *n* parallel channels **32***a*, **32***b* . . . and **32'***a*, **32'***b* . . . These partitions are made of refractory materials and prevent any parasite flow of liquid metal from top to bottom in the end pieces **30** and **39'**.

FIG. **5** is an end piece **49** comprising *n* openings **40***a*, **40***b* . . . whose cross-sections decrease from the lower part of the end piece to the upper part, following the metal flow in the duct, to take into account the possible variant of the field along the duct.

The openings **40** are extended by horizontal partitions. End pieces of that type give excellent results and enable the electrical resistance of the coil on the end of which they are installed to be reduced as much as possible.

The applicant has manufactured end pieces whose openings were extended by inclined partitions, this having, in certain cases, improved the metal flow in the duct.

The end pieces are, to great advantage, made of a ceramic substance, cement or compound materials.

Although the end pieces and the coil are manufactured separately, it is possible, in certain cases, to make this manufacturing easier, to manufacture simultaneously the end pieces, the casing of the coil and also the partitions, for example, by moulding in a same mould, so that the coil and end pieces then form only a single part.

Although the pump which has just been described appears to afford the greatest advantages for implementing the invention, it will be understood that various modifications may be made thereto without going beyond the scope of the invention, it being possible to replace certain of its elements by other elements capable of fulfilling the same technical function or an equivalent technical function therein.

We claim:

**1.** In a liquid metal conduction pump which may be immersed in said metal and which includes:

a first magnetic circuit provided at its upper part with a first feed winding and at its lower part with an air gap within which a horizontal magnetic field is set up by energization of a first feed winding,

a rectilinear duct extending vertically within said air gap for confining the liquid metal flow along a vertical axis crossing said air gap,

a second magnetic circuit provided at its upper part with a second supply winding and

a coil carried by said second magnetic circuit having an electrical current induced therein and having a middle plane portion extending through said air gap of said first magnetic circuit with the direction of the current being horizontal and orthogonal to the magnetic field in the section of liquid metal situated in said air gap.

the improvement wherein:

opposite sides of said duct at said air gap carry aligned openings and said coil comprises a closed refractory casing intersecting said rectilinear duct and terminating at its ends in open end pieces sealingly overlying said openings within respective sides of said rectilinear duct with said refractory casing containing said liquid metal,

whereby, a continuous loop of liquid metal flowing in said duct at the level of said air gap acts as a low impedance closed loop conductor for causing a large current to flow across the flow path of the liquid metal passing axially within the rectilinear duct and at right angles to the magnetic flux path across the air gap.

**2.** The conduction pump for liquid metal according to claim **1,** wherein: each end piece of said casing is constituted by an extension of said casing.

**3.** The conduction pump for liquid metal, according to claim **1,** wherein: each end piece comprises *n* openings separated by partitions dividing that end piece into n parallel channels.

**4.** The conduction pump for liquid metal according to claim **3,** wherein: each end piece of said casing is constituted by an extension of said casing.

**5.** The conduction pump for liquid metal, according to claim **3,** wherein: the cross-section of the openings decreases from the lower part of each end piece to the upper part, following the flow direction of the metal.

**6.** The conduction pump for liquid metal, according to claim **5,** wherein: each end piece of said casing is constituted by an extension of said casing.

**7.** The conduction pump for liquid metal, according to claim **1,** wherein: each end piece comprises *n* openings separated by partitions dividing the coil and the end pieces into *n* parallel channels.

8. The conduction pump for liquid metal, according to claim 7, wherein: each end piece of said casing is constituted by an extension of said casing.

9. The conduction pump for liquid metal, according to claim 7, wherein: the cross-section of the openings decreases from the lower part of each end piece to the upper part, following the flow direction of the metal.

10. The conduction pump for liquid metal, according to claim 9, wherein: each end piece of said casing is constituted by an extension of said casing.

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