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(54) MAGNETOHYDRODYNAMIC PUMPS FOR NON-CONDUCTIVE FLUIDS

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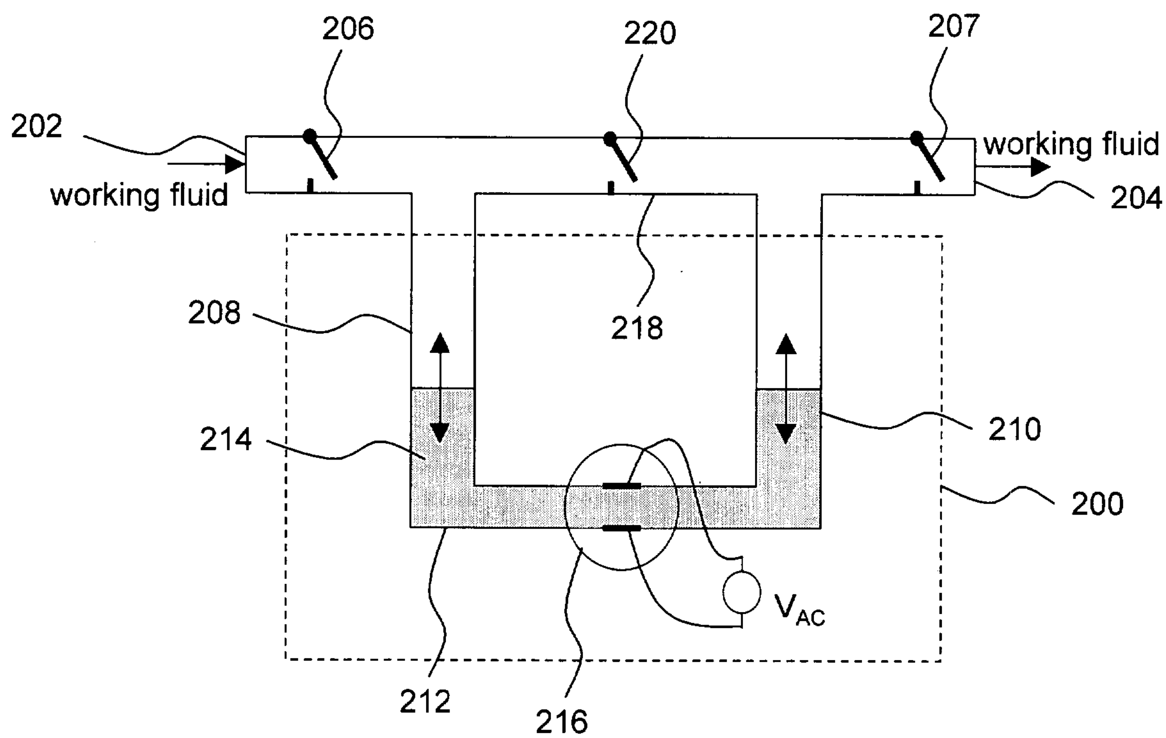
(57) **ABSTRACT**

The present invention provides an improved fluid pump that combines a liquid metal MHD pump with a plurality of fluid flow valves. The pump comprises a suction and pumping assembly, the suction and pumping assembly in turn comprising a first vertical chamber and a second vertical chamber connected using an intermediate horizontal chamber, a liquid metal partially filling the suction and pumping assembly, and an AC-powered reciprocating MHD pump. The AC-powered reciprocating MHD pump drives the liquid metal in an oscillatory manner, causing the suction and pumping of a working fluid. The pump further comprises at least one inlet conduit connected to the suction and pumping assembly for enabling the suction of a working fluid, at least one outlet conduit connected to the suction and pumping assembly for enabling the pumping of the working fluid, and a plurality of valves in the inlet and outlet conduits to regulate the flow of the working fluid.



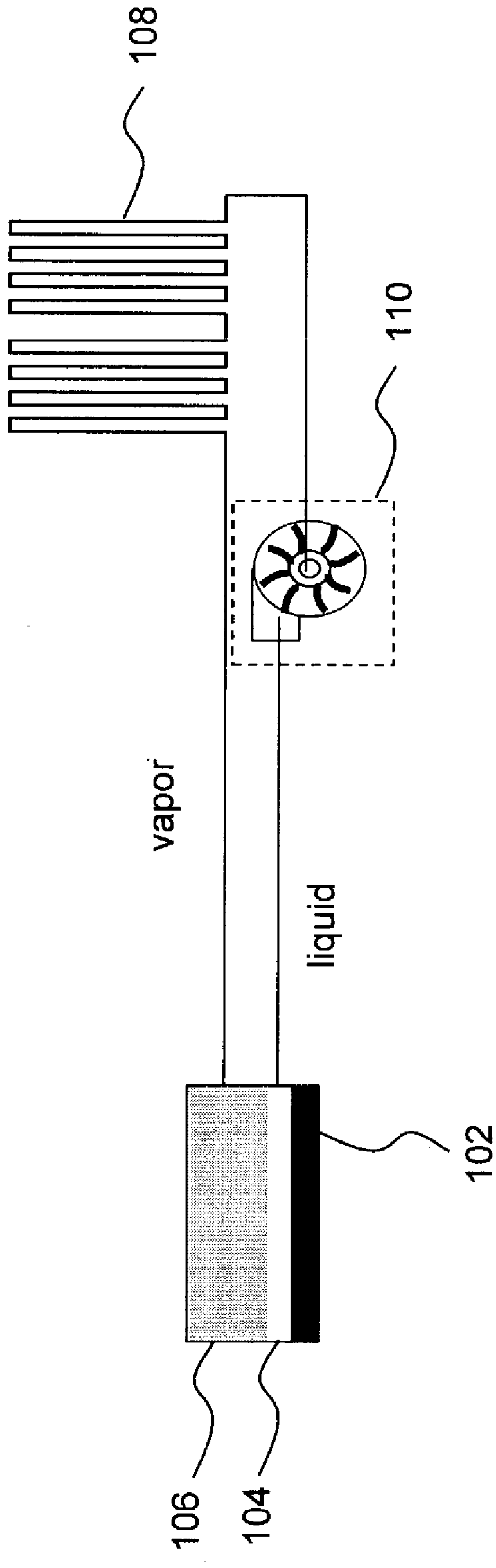


FIG. 1

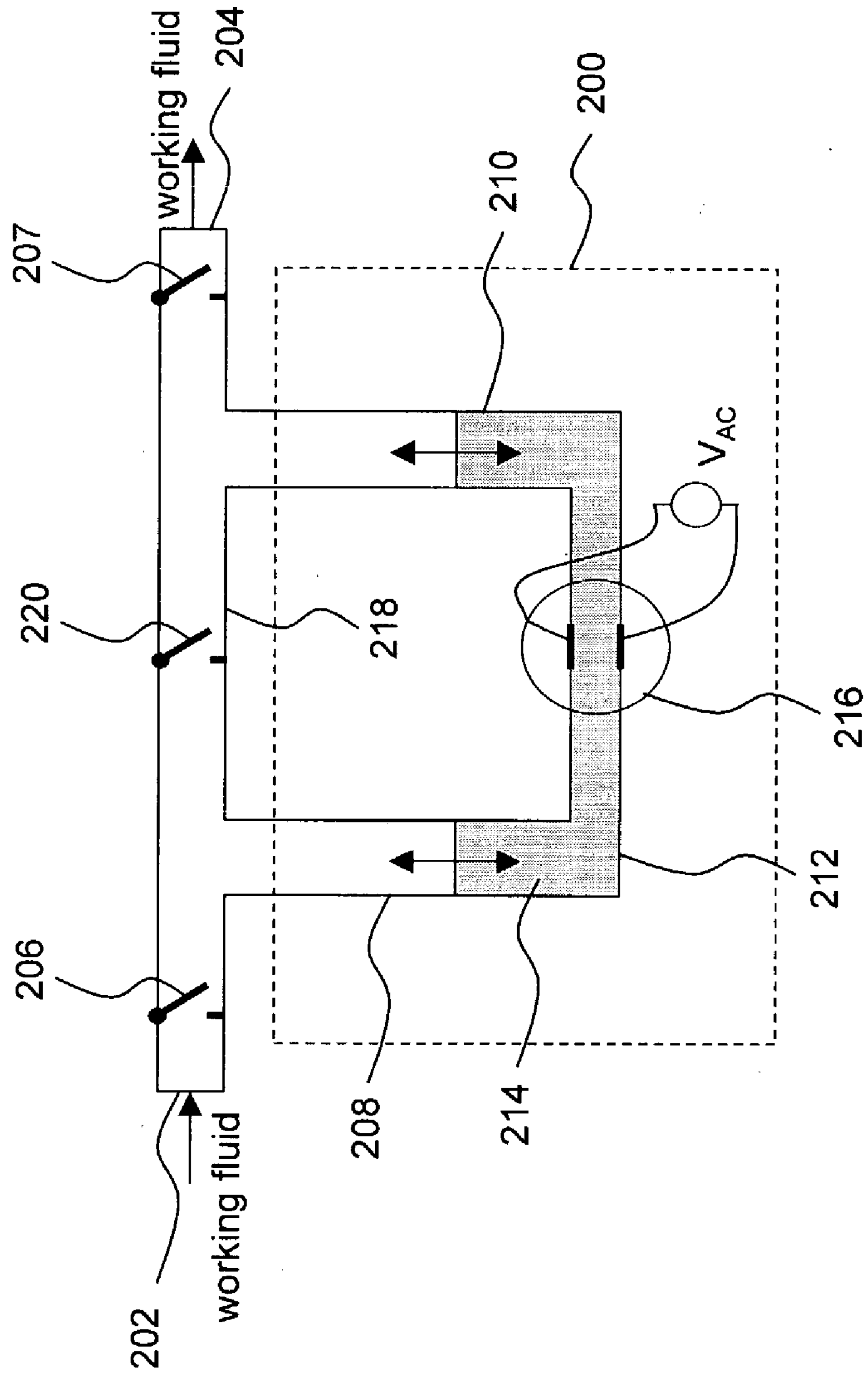

working fluid
204
207
200
210
VAC
220
218
216
212
206
202
working fluid
208
214

FIG. 2

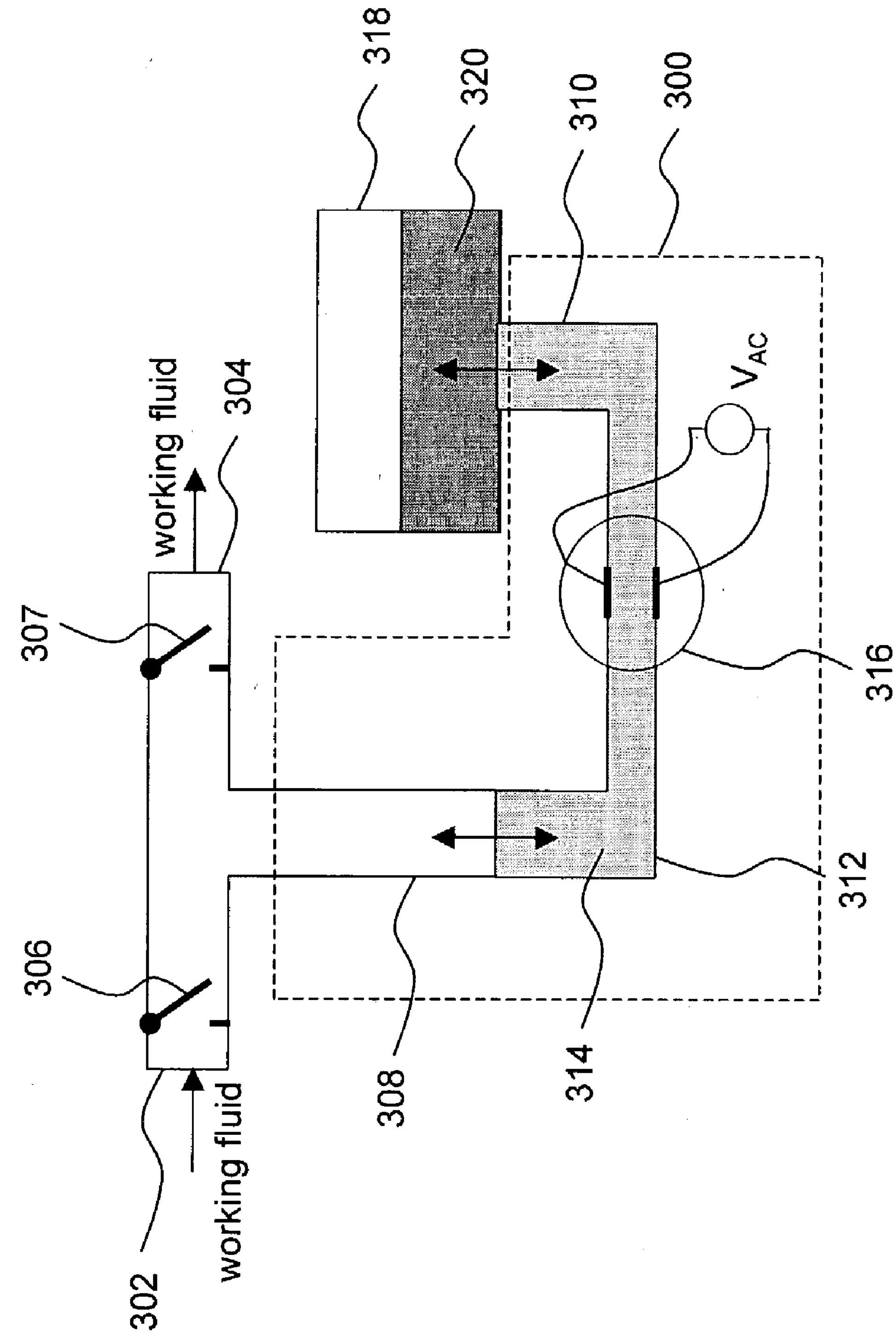

318
320
310
300
working fluid
304
307
V_{AC}
306
316
312
314
308
302
working fluid

FIG. 3

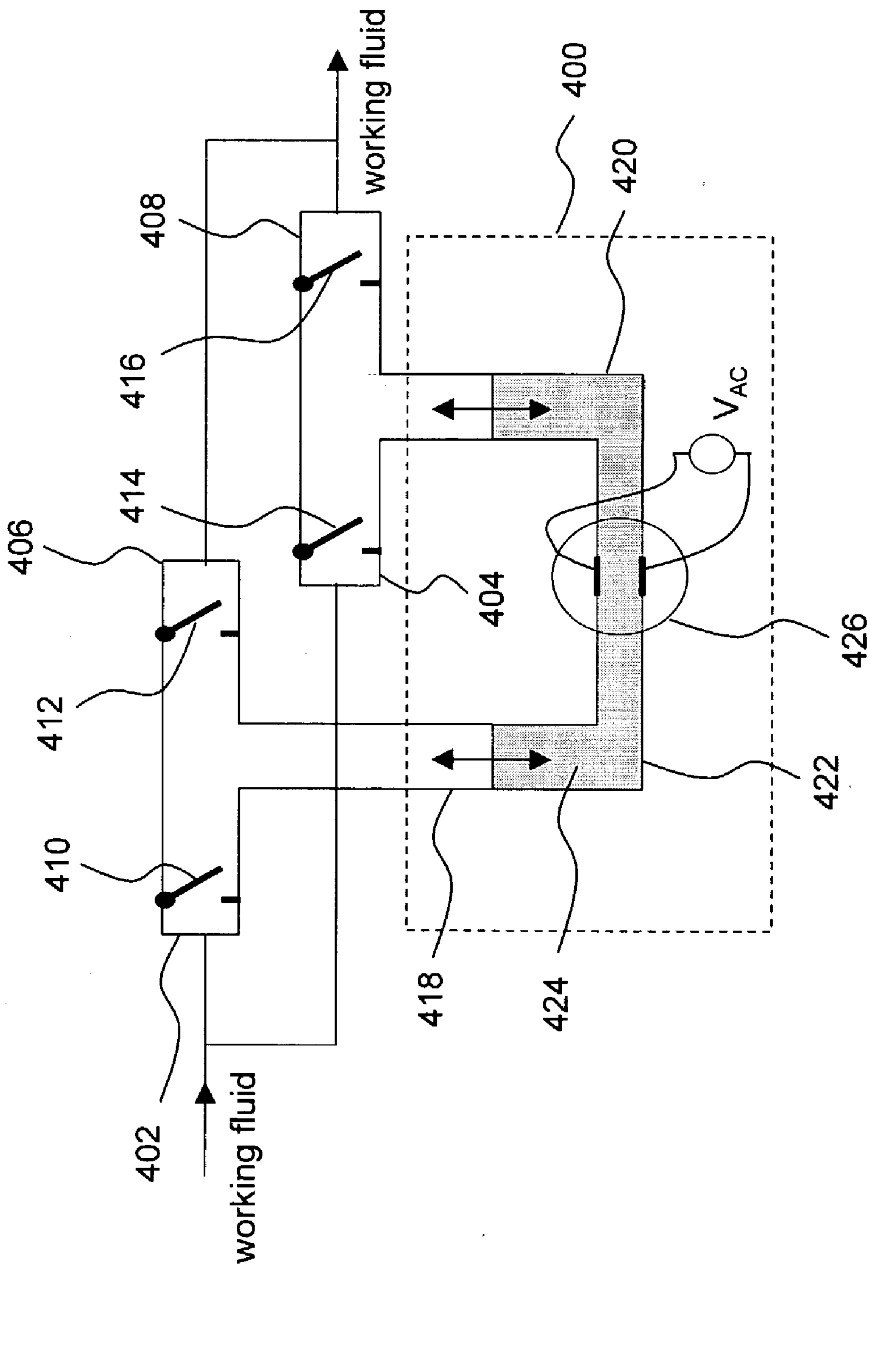

working fluid
working fluid
400
402
404
406
408
410
412
414
416
418
420
422
424
426
V_{AC}

FIG. 4

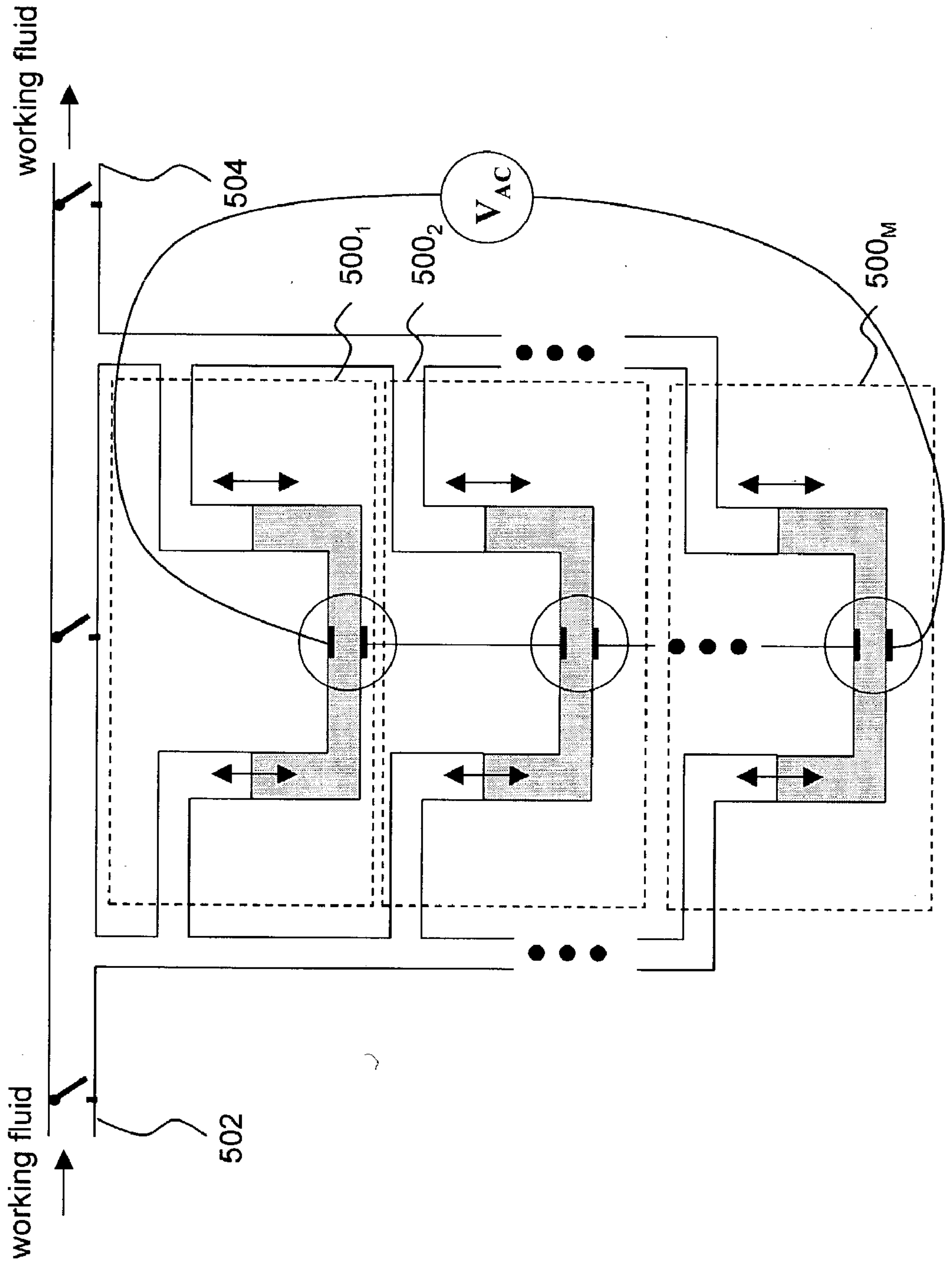


FIG. 5

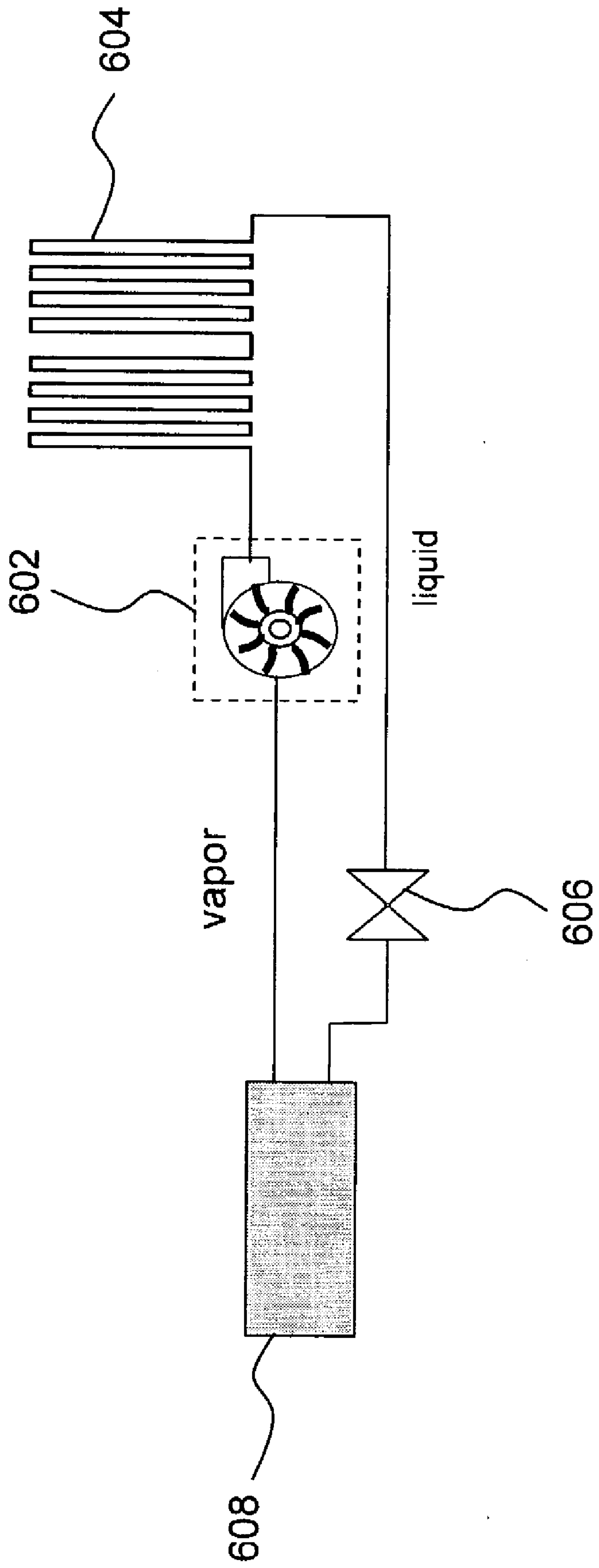


FIG. 6

MAGNETOHYDRODYNAMIC PUMPS FOR NON-CONDUCTIVE FLUIDS

BACKGROUND

[0001] The present invention relates to applications of magnetohydrodynamic (MHD) pumps. More particularly, it relates to the use of MHD pumps for pumping of non-conductive (dielectric) fluids.

[0002] Electronic devices such as central processing units, graphic-processing units and laser diodes as well as electrical devices, such as transformers, generate a lot of heat during operation. If generated heat is not dissipated properly from high power density devices, this may lead to temperature buildup in these devices. The buildup of temperature can adversely affect the performance of these devices. For example, excessive temperature buildup may lead to malfunctioning or breakdown of the devices. So, it is important to remove the generated heat in order to maintain normal operating temperatures of these devices. A number of cooling systems have been proposed for the removal of the generated heat.

[0003] Some proposed cooling systems, including the one referred previously, involve single phase cooling using liquid metal. These cooling systems use MHD pumps for controlling the flow of the coolant, i.e. liquid metal. A number of MHD pump configurations exist in prior art.

[0004] MHD pumps, such as the one referred to previously, can attain high mass flow rates (~50 g/s in miniature pumps) at sub-1W power dissipation levels. The excellent fluid flow characteristics combined with high thermal conductivities of liquid metals result in better extraction of heat from the source and better rejection in the ambient heat exchanger.

[0005] However, in some applications, the advantages offered by using liquid metal are offset by other considerations such as the high volume, high weight and high electrical conductivity of the liquid metal. For example, in portable systems such as laptops and notebooks, the high volume and weight of liquid metals is a restriction on their use as coolants. Moreover, in case of cooling of high voltage power supplies and transformers, the use of electrically conductive liquid metals is not recommended. For such applications, non-conductive fluids such as water may be used. Further, two-phase cooling may be employed so as to benefit from the high latent heat of vaporization of the coolants. One such two-phase cooling system is illustrated in **FIG. 1**. The two-phase cooling system is used for cooling a hot source **102**. Hot source **102** may be a microelectronic chip, an optoelectronic chip, a laser diode, a light emitting diode (LED), a high voltage power supply, a central processing unit of a computer etc. A coolant **104** present in evaporator **106** is vaporized on the surface of hot source **102**, resulting in the extraction of heat from hot source **102**. The vapor so formed is transferred to a condenser **108** that rejects heat to the ambient atmosphere and liquefies the vapor. The coolant so formed is re-circulated over hot source **102** with the help of a pump **110**.

[0006] Pump **110** may be a conventional pump. However, MHD pumps are more reliable and safe compared to other pumps, as MHD pumps do not have any mobile parts (with the exception of the conductive fluid itself). Therefore, an MHD pump may be used so as to benefit from the advantages offered by an MHD pump over a conventional pump. However, an MHD pump needs to be adapted for the purpose of pumping a non-conductive fluid.

[0007] One such adaptation of an MHD pump for fluid pumping is discussed in U.S. Pat. No. 6,241,480, titled "Micro-Magnetohydrodynamic Pump And Method For Operation Of The Same". The patent discloses a system in which a valving liquid metal piston and a pumping liquid metal piston are used for pumping fluids. The valving piston regulates the flow the fluid in and out of the system, while the pumping liquid metal piston pumps enables the suction and pumping of the fluid. Both the liquid metal pistons are driven magnetohydrodynamically in an oscillatory manner (the direction of motion of the pistons is varied periodically). However, this system suffers from certain disadvantages. Firstly, the movement of the two liquid metal pistons has to be synchronized for proper functioning. Secondly, the system produces discontinuous outflow of the fluid since the outflow is restricted to half the oscillatory cycle of the pistons (in one particular embodiment, fluid is pumped out only when the valving piston moves to the left and the pumping piston moves up, and not in the reverse movement). Thirdly, the valve action is based on the surface tension properties of liquid metals resulting in poor pressure heads and poor mean time between failures (MTBF).

[0008] Hence, there is a need for an improved pump for fluid pumping applications.

SUMMARY

[0009] The present invention is directed to an improved pump for pumping of fluids, specifically non-conductive (dielectric) fluids.

[0010] An object of the present invention is to provide an improved fluid pump that combines the advantages of liquid metal MHD pumps with the advantages of high reliability fluid flow valves.

[0011] Another object of the present invention is to provide a non-bulky fluid pump that is suitable for use for two-phase cooling using non-conductive fluids in portable systems such as laptops.

[0012] Another object of the present invention is to provide a safer fluid pump that has a lesser number of movable parts as compared to conventional pump.

[0013] Another object of the present invention is to provide an improved fluid pump that is suitable for use for two-phase cooling using non-conductive fluids in high voltage systems such as transformers.

[0014] A further object of the present invention is to provide an improved fluid pump that is suitable for use as a vapor compressor in a vapor compression system.

[0015] To achieve the foregoing objectives, and in accordance with the purpose of the present invention as broadly described herein, the present invention provides an improved fluid pump. The pump combines a liquid metal MHD pump with a plurality of fluid flow valves for enabling good pumping performance. The pump provided by the present invention comprises a suction and pumping assembly, the suction and pumping assembly in turn comprising a first vertical chamber and a second vertical chamber connected using an intermediate horizontal chamber. Liquid metal partially fills the first vertical chamber and the second vertical chamber of the suction and pumping assembly. An AC-powered reciprocating MHD pump is provided for driving the liquid metal in the chambers of the suction and pumping assembly in an oscillatory manner. The pump further comprises at least one inlet conduit connected to the suction and pumping assembly, at least one outlet conduit connected to the suction and pumping assembly and a plurality of valves in the inlet and outlet conduits. The inlet conduits enable the suction of a working fluid into the suction and pumping assembly. The outlet conduits enable the pumping of the working fluid out of the suction and pumping assembly The valves in the inlet conduits and the outlet conduits control the flow of the working fluid in and out of the pump. The suction and the pumping of the working fluid are caused by the oscillatory motion of the liquid metal in the suction and pumping assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The preferred embodiments of the invention will hereinafter be described in conjunction with the appended drawings provided to illustrate and not to limit the invention, wherein like designations denote like elements, and in which:

[0017] **FIG. 1** is a block diagram of a two-phase cooling system;

[0018] **FIG. 2** illustrates a fluid pump in accordance with a first embodiment of the present invention;

[0019] **FIG. 3** illustrates a fluid pump in accordance with a second embodiment of the present invention;

[0020] **FIG. 4** illustrates a fluid pump in accordance with a third embodiment of the present invention;

[0021] **FIG. 5** illustrates a fluid pump in accordance with a fourth embodiment of the present invention; and

[0022] **FIG. 6** is a block diagram of a vapor compression system, of which the present invention forms a part.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0023] The present invention provides a pump for pumping of working fluids. More particularly, the invention provides pump for pumping of non-conductive fluids.

[0024] The pump combines fluid flow valves with liquid metal and an AC-powered reciprocating MHD pump. The valves are used to provide direction to the flow of the working fluid. The AC-powered MHD pump is used to drive the liquid metal in an oscillatory manner, the motion of the liquid metal enabling the suction and pumping of the working fluid.

[0025] Referring now primarily to **FIG. 2**, the structure of the pump in accordance with a first embodiment of the present invention will hereinafter be described. The pump in accordance with the first embodiment comprises a suction and pumping assembly **200** for sucking and pumping the working fluid, an inlet conduit **202** for allowing inflow of the working fluid, an outlet conduit **204** for allowing outflow of the working fluid and a valve **206** in inlet conduit **202** and a valve **207** in outlet conduit **204**.

[0026] Suction and pumping assembly **200** comprises three hollow chambers—a first (left) vertical chamber **208**, a second (right) vertical chamber **210** and an intermediate horizontal chamber **212**. First vertical chamber **208** and second vertical chamber **210** are both partially filled with a liquid metal **214**. Intermediate horizontal chamber **212** is completely filled with liquid metal **214**. Liquid metal **214** is driven in an oscillatory manner by an AC-powered reciprocating MHD pump **216** connected to intermediate horizontal chamber **212**.

[0027] Inlet conduit **202** is connected to first vertical chamber **208** and outlet conduit **204** is connected to second vertical chamber **210**. Moreover, first vertical chamber **208** and second vertical chamber **210** are connected through an intermediate conduit **218** to enable the transfer of the working fluid. Intermediate conduit **218** has a valve **220** for ensuring the unidirectional transfer of the working fluid from first vertical chamber **208** to second vertical chamber **210**.

[0028] The working fluid is sucked into first vertical chamber **208** through inlet conduit **202**, transferred to second vertical chamber **210** through intermediate conduit **218** and pumped out through outlet conduit **204**. The suction, transfer and pumping of the working fluid is achieved by the oscillatory motion of liquid metal **214**. This oscillatory motion of liquid metal **214** is governed by cycles of the AC supply that drives AC-powered reciprocating MHD pump **216**.

[0029] During one half of the AC cycle, liquid metal **214** in first vertical chamber **208** is driven down. As a result, the working fluid is sucked into first vertical chamber **208** through inlet conduit **202**. During the same AC cycle, the working fluid already in second vertical chamber **210** is pumped out through outlet conduit **204**. Valve **220** ensures that the working fluid is not transferred from second vertical chamber **210** to first vertical chamber **208** during this cycle.

[0030] During the other half of the AC cycle, liquid metal **214** in first vertical chamber **208** is driven up. As a result, the working fluid is transferred from first vertical chamber **208** to second vertical chamber **210** through intermediate conduit **218**. Valve **206** ensures that the working fluid is not pumped out of first vertical chamber **208** through inlet conduit **202** in this cycle. Valve **207** ensures that the working fluid is not sucked into second vertical chamber **210** through outlet conduit **204** in this cycle.

[0031] This embodiment results in a half-rectified (discontinuous) flow of the working fluid, with the outflow and inflow of the working fluid being synchronized.

[0032] Referring now primarily to **FIG. 3**, the structure of the pump in accordance with a second embodiment of the present invention will hereinafter be described. The pump in accordance with the second embodiment comprises a suction and pumping assembly **300** for sucking and pumping the working fluid, an inlet conduit **302** for allowing the inflow of the working fluid, an outlet conduit **304** for allowing the outflow of the working fluid and a valve **306** in inlet conduit **302** and a valve **307** in outlet conduit **304**.

[0033] Suction and pumping assembly **300** comprises three hollow chambers—a first vertical chamber **308**, a second vertical chamber **310** and an intermediate horizontal chamber **312**. First vertical chamber **308** is partially filled and second vertical chamber **310** is completely filled with a liquid metal **314**. Intermediate horizontal chamber **312** is completely filled with liquid metal **314**. Liquid metal **314** is driven in an oscillatory manner by an AC-powered reciprocating MHD pump **316** connected to intermediate horizontal chamber **312**.

[**0034**] Inlet conduit **302** and outlet conduit **304** are both connected to first vertical chamber **308**. Second vertical chamber **310** is connected to a reservoir **318** filled with an inert fluid **320**. Inert fluid **320** may be any fluid that does not react with liquid metal **314** and prevents surface oxidation. Examples of such fluid include Fluorinert and weakly acidic water with pH between 3 and 4.

[**0035**] The working fluid is sucked into first vertical chamber **308** through inlet conduit **302** and pumped out through outlet conduit **304**. The suction and pumping of the working fluid is achieved by the oscillatory motion of liquid metal **314**. This oscillatory motion of the liquid metal **314** is governed by cycles of the AC supply that drives AC-powered reciprocating MHD pump **316**.

[**0036**] During one half of the AC cycle, liquid metal **314** in first vertical chamber **308** is driven down. As a result, the working fluid is sucked into first vertical chamber **308** through inlet conduit **302**. Valve **307** ensures that the working fluid is not sucked into first vertical chamber **308** through outlet conduit **304** during this cycle. During the other half of the AC cycle, liquid metal **314** in first vertical chamber **308** is driven up. As a result, the working fluid is pumped out through outlet conduit **304**.

[**0037**] Valve **306** ensures that the working fluid is not pumped out of first vertical chamber **308** through inlet conduit **302** during this cycle.

[**0038**] Hence, this embodiment results in a half-rectified (discontinuous) flow of the working fluid, with the inflow and outflow of the working fluid being out of phase.

[**0039**] Referring now primarily to **FIG. 4**, the structure of the pump in accordance with a third embodiment of the present invention will hereinafter be described. The apparatus in accordance with the third embodiment comprises a suction and pumping assembly **400** for sucking and pumping the working fluid, two inlet conduits **402** and **404** for the inflow of the working fluid, two outlet conduits **406** and **408** for the outflow of the working fluid and four valves **410**, **412**, **414** and **416**, one in each conduit.

[**0040**] Suction and pumping assembly **400** comprises three hollow chambers—a first vertical chamber **418**, a second vertical chamber **420** and an intermediate horizontal chamber **422**. First vertical chamber **418** and second vertical chamber **420** are both partially filled with a liquid metal **424**. Intermediate horizontal chamber **422** is completely filled with liquid metal **424**. Liquid metal **424** is driven in an oscillatory manner by an AC-powered reciprocating MHD pump **426** connected to intermediate horizontal chamber **422**.

[**0041**] Inlet conduit **402** and outlet conduit **406** are connected to first vertical chamber **408**. On the other hand, inlet conduit **404** and outlet conduit **408** are connected to second vertical chamber **420**.

[**0042**] The working fluid is sucked into either first vertical chamber **418** through inlet conduit **402** or into second vertical chamber **420** through inlet conduit **404**. Thereafter, the working fluid is pumped out of the same chamber it was sucked into, through either outlet conduit **406** or outlet conduit **408**. For example, in case the working fluid is sucked into first vertical chamber **418**, it will be pumped out of the same chamber through outlet conduit **406**. The suction, transfer and pumping of the working fluid is achieved by the oscillatory motion of liquid metal **424**. This oscillatory motion of liquid metal **424** is governed by cycles of the AC supply that drives AC-powered reciprocating MHD pump **426**.

[**0043**] During one half of the AC cycle, liquid metal **424** in first vertical chamber **418** is driven down. As a result, the working fluid is sucked into first vertical chamber **418** through inlet conduit **402**. The downward motion of liquid metal **424** in first vertical chamber **418** causes an upward motion of liquid metal **424** in second vertical chamber **420**. This causes the working fluid in this chamber to be pumped out through outlet conduit **408**. Valve **412** ensures that the working fluid is not sucked into first vertical chamber **418** through outlet conduit **406** during this cycle. Moreover, valve **414** ensures that the working fluid is not pumped out of second vertical chamber **420** through inlet conduit **404** during this cycle.

[**0044**] During the other half of the AC cycle, liquid metal **424** in first vertical chamber **418** is driven up. As a result, the working fluid is pumped out of first vertical chamber **418** through outlet conduit **406**. The upward motion of liquid metal **424** in first vertical chamber **418** causes a downward motion of liquid metal **424** in second vertical chamber **420**. This causes the working fluid to be sucked in to second vertical chamber **420** through inlet conduit **404**. Valve **410** ensures that the working fluid is not pumped out of first vertical chamber **418** through inlet conduit **402** during this cycle. Moreover, valve **416** ensures that the working fluid is not sucked into second vertical chamber **420** through outlet conduit **408** during this cycle.

[**0045**] This embodiment results in a fully rectified (almost continuous) flow of the working fluid.

[**0046**] In a fourth embodiment of the present invention, suction and pumping assemblies, in accordance with any of the previously discussed embodiments, are combined in parallel. Such a structure results in an increase in the pumping capacity and pressure head. This results in an increase in the power of the pump. Referring now primarily to **FIG. 5**, an exemplary structure of the pump in accordance with the fourth embodiment of the present invention will hereinafter be described. Suction and pumping assemblies $\mathbf{500}_1$ to $\mathbf{500}_M$, corresponding to the first embodiment of the pump (shown in **FIG. 2**), are combined in parallel. The working fluid flows into suction and pumping assemblies $\mathbf{500}_1$ to $\mathbf{500}_M$ through an inlet conduit **502** and is pumped out through an outlet conduit **504**.

[**0047**] The operating voltage of the pump provided by this embodiment is proportional to the number of suction and pumping assemblies connected in parallel. This provides flexibility for increasing the operating voltage of the pump. Higher operating voltage may be desirable in some cases due to the following reason.

[**0048**] Conventional pumps operate at a voltage of <20 mV. On the other hand, voltages provided by typical power supplies are of the order of 5-100V. This requires the downconversion of the supply voltage to the low operating voltage of the pump. The efficiency of downconversion becomes smaller (<90%) for voltage downconversion ratios >100. The size of the downconverting circuit also becomes large when the voltage downconversion ratios are large. The above-mentioned embodiment allows operation at an increased voltages and lower voltage downconversion ratios.

[0049] In the embodiments of the present invention, the suction and pumping assembly has been shown as a U-shaped structure. It will be apparent to one skilled in the art that the suction and pumping assembly can have other similar shapes including but not limited to a distorted U-shape (where the angles between the horizontal intermediate chamber and the first and second vertical chambers are different from 90°).

[0050] In all the above-mentioned embodiments of the present invention, one-way moving valves such as ball and cage valves and flapper valves may be used. Alternatively, non-moving valves such as Tesla valves may be used. U.S. Pat. No. 6,227,801 titled "Method For Making Micropump" describes the use of non-moving valves in miniature pumps. The valves used in the abovementioned embodiments, do not need external control i.e. their operation is only dependent on the pressure differences across the valve.

[0051] A number of different liquid metals may be used in the above-mentioned embodiments without departing from the scope of the invention. For example, liquid metals having high thermal conductivity, high electrical conductivity and high volumetric heat capacity can be used. Some examples of liquid metal that can be used in the above-mentioned embodiments include: sodium potassium eutectic alloy, gallium-indium alloy, mercury, bismuth, indium and gallium. Also, a number of working fluids can be used in the invention. The working fluid should not react with gallium or form oxides or any compound that result in long term fouling. Typical examples of such working fluids include slightly acidic water with pH between 3 and 4, fluorinerts, CFCs, R134a, and Puron. The pumps can also be used for pumping air if the surface of liquid metal is covered with inert fluid or nitrogen or any inert gas. The chambers of the suction and pumping assembly as well as the inlet and outlet conduits can be constructed of polymer materials such as Teflon or polyurethane. Tungsten or nickel-coated copper can be used as electrodes.

[0052] The pump provided by the present invention delivers maximum power efficiency at an optimal resonant frequency. This optimal resonant frequency in turn depends on factors such as the volume of the working fluid transferred between the first and second chambers, the external pressure head, length of the chambers and the diodicity (flow to leakage ratio) of the valves. For example, for a pump with 1-2 cm^3 of working fluid with density of 1-2 g/cc, the optimal resonant frequency is in the range of 1-30 Hz, the exact value depending on the other factors.

[0053] Referring back to **FIG. 1**, an application of the present invention will hereinafter be discussed. As described previously, **FIG. 1** shows a general two-phase cooling system. The pump provided by the present invention is used in such a two-phase cooling system as pump **110**. In the preferred embodiment of the system provided by the present invention, Fluorinert is used as the coolant i.e. the working fluid. Fluorinert is a colorless, fully fluorinated liquid such as Fluorinert™ Electronic Liquid FC-72 provided by 3M.

[0054] The pump provided by the present invention can also be used as a vapor compressor. Referring now primarily to **FIG. 6**, an application of the pump as a vapor compressor will hereinafter be discussed. **FIG. 6** shows a vapor compression system, commonly used in air-conditioners and refrigerators. A refrigerant fluid such as R134a is converted from a low pressure vapor state to a high pressure fluid by a compressor **602**. The high pressure fluid is cooled at a condenser **604** by rejecting the heat to the ambient atmosphere. The high pressure is next released through an expansion valve **606** to a cold end chamber or evaporator **608**. The expansion results in cooling of the fluid and subsequent extraction of heat from the walls of cold end chamber or evaporator **608**. This low-pressure refrigerant is re-circulated into compressor **602**. The present invention can be used in the vapor compression system as compressor **602**.

[0055] The present invention offers several advantages over prior art. Firstly, the use of high reliability valves such as ball and cage valves and Tesla valves results in improved fluid flow performance. Secondly, the present invention is capable of providing a variety of fluid flow profiles (both continuous and discontinuous flow). Thirdly, the pump provided by the present invention has low weight and volume and is thus suitable for use in portable systems. Fourthly, the pump has less moving parts than conventional pumps and is thus safer. Finally, the pump is suitable for use in high-voltage systems due to its ability of pumping non-conductive fluids.

[0056] While the preferred embodiments of the invention have been illustrated and described, it will be clear that the invention is not limited to these embodiments only. Numerous modifications, changes, variations, substitutions and equivalents will be apparent to those skilled in the art without departing from the spirit and scope of the invention as described in the claims.

What is claimed is:

1. An apparatus for pumping a working fluid, the apparatus comprising:

a. a suction and pumping assembly comprising:

i. a first vertical chamber and a second vertical chamber connected using an intermediate horizontal chamber,

ii. liquid metal partially filling the vertical chambers of the suction and pumping assembly, and

iii. an AC-powered reciprocating MHD pump for driving the liquid metal in the chambers of the suction and pumping assembly in an oscillatory manner;

b. at least one inlet conduit connected to the suction and pumping assembly, the inlet conduit allowing the working fluid to be sucked into the suction and pumping assembly, the working fluid being sucked in due to the oscillatory motion of the liquid metal;

c. at least one outlet conduit connected to the suction and pumping assembly, the outlet conduit allowing the working fluid to be pumped out of the suction and pumping assembly, the working fluid being pumped out due to the oscillatory motion of the liquid metal; and

d. a plurality of valves in the inlet and outlet conduits for controlling the inlet and outlet flow of the working fluid.

2. The apparatus as recited in claim 1 wherein the suction and pumping assembly is U-shaped.

3. The apparatus as recited in claim 1 wherein the working fluid is a non-conductive fluid.

4. The apparatus as recited in claim 3 wherein each of the plurality of valves is a one-way valve.

5. The apparatus as recited in claim 3 wherein each of the plurality of valves is a Tesla valve.

6. The apparatus as recited in claim 1 wherein the apparatus comprises only one inlet conduit and only one outlet conduit.

7. The apparatus as recited in claim 6 wherein the inlet conduit and the outlet conduit have one valve each.

8. The apparatus as recited in claim 7 wherein the inlet conduit is connected to the first vertical chamber of the suction and pumping assembly and the outlet conduit is connected to the second vertical chamber of the suction and pumping assembly.

9. The apparatus as recited in claim 8 wherein the liquid metal partially fills both the first vertical chamber of the suction and pumping assembly and the second vertical chamber of the suction and pumping assembly.

10. The apparatus as recited in claim 9 wherein the pumping is achieved by:

a. the AC-powered reciprocating MHD pump driving down the liquid metal in the first vertical chamber of the suction and pumping assembly during one half of the AC cycle, the driving down of the liquid metal causing the sucking in of the working fluid into the first vertical chamber of the suction and pumping assembly through the inlet conduit and the pumping out of the working fluid through an outlet conduit of the suction and pumping assembly;

b. the AC-powered reciprocating MHD pump driving up the liquid metal in the first vertical chamber of the suction and pumping assembly during the other half of the AC cycle, the driving up of the liquid metal causing the working fluid to be transferred from the first vertical chamber to the second vertical chamber of the suction and pumping assembly through an intermediate conduit, the intermediate conduit connecting the first vertical chamber and the second vertical chamber.

11. The apparatus as recited in claim 10 wherein the intermediate conduit contains a valve to control the transfer of the working fluid between the first vertical chamber and the second vertical chamber.

12. The apparatus as recited in claim 7 wherein both the inlet conduit and the outlet conduit are connected to the first vertical chamber of the suction and pumping assembly.

13. The apparatus as recited in claim 12 wherein the liquid metal partially fills the first vertical chamber of the suction and pumping assembly and completely fills the second vertical chamber of the suction and pumping assembly.

14. The apparatus as recited in claim 13 wherein the second vertical chamber of the suction and pumping assembly is connected to a reservoir of inert fluid.

15. The apparatus as recited in claim 14 wherein the pumping is achieved by:

a. the AC-powered reciprocating MHD pump driving down the liquid metal in the first vertical chamber of the suction and pumping assembly during one half of the AC cycle, the driving down of the liquid metal causing the sucking in of the working fluid into the first vertical chamber of the suction and pumping assembly through the inlet conduit;

b. the AC-powered reciprocating MHD pump driving up the liquid metal in the first vertical chamber of the suction and pumping assembly during the other half of the AC cycle, the driving up of the liquid metal causing the pumping out of the working fluid through the outlet conduit of the second vertical chamber of the suction and pumping assembly.

16. The apparatus as recited in claim 1 wherein the apparatus comprises two inlet conduits and two outlet conduits.

17. The apparatus as recited in claim 16 wherein the inlet conduits and the outlet conduits have one valve each.

18. The apparatus as recited in claim 17 wherein one inlet conduit and one outlet conduit are connected to the first vertical chamber of the suction and pumping assembly, the other inlet conduit and the other outlet conduit are connected to the second vertical chamber of the suction and pumping assembly.

19. The apparatus as recited in claim 18 wherein the liquid metal partially fills both the first vertical chamber of the suction and pumping assembly and the second vertical chamber of the suction and pumping assembly.

20. The apparatus as recited in claim 19 wherein the pumping is achieved by:

a. the AC-powered reciprocating MHD pump driving down the working fluid in a vertical chamber of the suction and pumping assembly during one half of the AC cycle, the driving down of the liquid metal causing the sucking in of the working fluid into the corresponding vertical chamber of the suction and pumping assembly through the corresponding inlet conduit;

b. the AC-powered reciprocating MHD pump driving up the working fluid in a vertical chamber of the suction and pumping assembly during the other half of the AC cycle, the driving up of the liquid metal causing the pumping out of the working fluid from the corresponding vertical chamber of the suction and pumping assembly through the corresponding outlet conduit;

21. The apparatus as recited in claim 1 wherein the apparatus comprises a plurality of suction and pumping assemblys connected in parallel.

22. The apparatus as recited in claim 1 wherein the apparatus is used as a pump in a two-phase cooling system

23. The apparatus as recited in claim 1 wherein the apparatus is used as a compressor in a vapor compression system.

24. A system for two-phase cooling of a hot source, the system comprising:

a. an evaporator placed adjacent to the hot source, the evaporator absorbing the heat from the hot source causing the evaporation of a coolant circulating over the hot source;

b. a first conduit connected to the evaporator for the transfer of the vapor formed as a result of the evaporation of the coolant;

c. a condenser connected to the first conduit for liquefying the vapor;

d. a second conduit connected to the condenser for transfer of the liquid formed as a result of liquefying the vapor.

e. a fluid pump connected to the second conduit, the fluid pump comprising:

i. a suction and pumping assembly comprising:

1. a first vertical chamber and a second vertical chamber connected using an intermediate horizontal chamber,

2. liquid metal partially filling the chambers of the suction and pumping assembly, and

3. an AC-powered reciprocating MHD pump for driving the liquid metal in the chambers of the suction and pumping assembly in an oscillatory manner;

ii. at least one inlet conduit connected to the suction and pumping assembly, the inlet conduit allowing the liquid to be sucked into the suction and pumping assembly, the liquid being sucked in due to the oscillatory motion of the liquid metal;

iii. at least one outlet conduit connected to the suction and pumping assembly, the outlet conduit allowing the liquid to be pumped out of the suction and pumping assembly, the liquid being pumped out due to the oscillatory motion of the liquid metal; and

iv. a plurality of valves in the inlet and outlet conduits for controlling the inlet and outlet flow of the liquid; and

v. a third conduit connected to the fluid pump for transfer of the liquid back to the evaporator.

25. A system vapor compression, the system comprising:

a. an evaporator for evaporation of a refrigerant at low pressure;

b. a first conduit connected to the evaporator for the transfer of the low pressure vapor formed as a result of the evaporation of the refrigerant;

c. a compressor connected to the second conduit, the compressor converting the low pressure vapor into high pressure vapor, the compressor comprising:

i. a suction and pumping assembly comprising:

1. a first vertical chamber and a second vertical chamber connected using an intermediate horizontal chamber,

2. liquid metal partially filling the chambers of the suction and pumping assembly, and

3. an AC-powered reciprocating MHD pump for driving the liquid metal in the chambers of the suction and pumping assembly in an oscillatory manner;

ii. at least one inlet conduit connected to the suction and pumping assembly, the inlet conduit allowing the low pressure vapor to be sucked into the suction and pumping assembly, the low vapor being sucked in due to the oscillatory motion of the liquid metal;

iii. at least one outlet conduit connected to the suction and pumping assembly, the outlet conduit allowing the high pressure vapor to be pumped out of the suction and pumping assembly, the high pressure vapor being pumped out due to the oscillatory motion of the liquid metal; and

iv. a plurality of valves in the inlet and outlet conduits for controlling the inlet and outlet flow of the vapor;

d. a condenser connected to the first conduit for liquefying the high pressure vapor;

e. a second conduit connected to condenser for transfer of the high pressure refrigerant formed as a result of liquefying the vapor;

f. a valve connected to the second conduit for converting the high pressure refrigerant to a low pressure refrigerant; and

g. a third conduit connected to the valve to enable the circulation of the refrigerant.

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