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(12) # EUROPEAN PATENT APPLICATION

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(54) **Heat pump device**

(57) Heat pump device, particularly adapted for use in connection with a clothes drying machine or a machine intended to heat up a mass of water, comprising an electric heater (20; 120) adapted to transfer thermal energy to a refrigerant medium in a portion of a closed-loop circuit, through which said refrigerant medium is intended to flow, extending form an evaporator means (46; 146) and a compressor (40; 140); said electric heater (20, 120) comprises a fluid-tight casing (22) provided with attachment end portions (24, 26) adapted to be connected to a pipe, and contains at least a heating element (28) adapted to be submerged by said refrigerant medium.

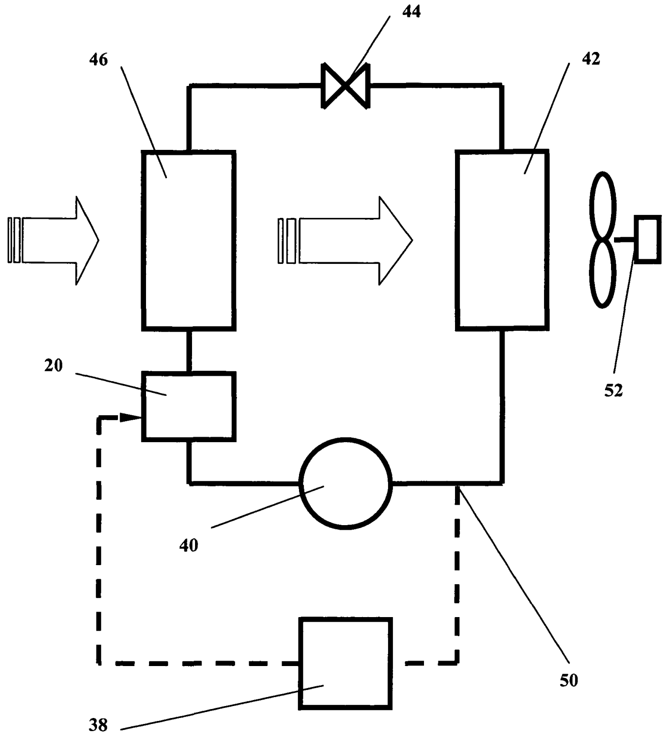


Fig. 3



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## Description

**[0001]** The present invention relates to a heat pump device, particularly adapted for use in connection with a clothes drying machine or a machine intended to heat up a mass of water.

**[0002]** A heat pump device of this kind is generally known to be comprised of a closed-loop circuit, through which there circulates a fluid, known as refrigerant medium in the art, which, thanks to the chemical-physical properties thereof, is effective in transferring heat from a colder environment to a heat-energy using function as it undergoes corresponding phase changes through a thermodynamic cycle (compression, condensation, expansion and evaporation).

**[0003]** During a compression step of the cycle, the refrigerant medium in a gas phase thereof undergoes the action of a compressor, which causes the same refrigerant medium to undergo an increase in both temperature and pressure. In a condensation step, the refrigerant medium flows through a heat exchanger, generally known as condenser in the art, where it gives off heat to the outside environment therearound, while changing its state from gas to liquid. At this point of the cycle, a further medium such as air or water provided to flush the condenser from the outside represents a so-called vector medium, or process medium, which uses the heat released by the refrigerant medium to heat up a high-temperature heat-energy using function. In an expansion step, the refrigerant medium flows through an expansion valve (throttling), which causes the refrigerant medium to undergo a pressure drop and, as a result, a decrease in temperature. In an evaporation step, the refrigerant medium is forced to flow into another heat exchanger, generally termed an evaporator in the art, where it vaporizes to thereby absorb, i.e. subtract heat and, therefore, thermal energy from the cold environment. Thereupon, the refrigerant medium flows back to the compressor to thereby start a new cycle as described above.

**[0004]** Such heat pump device may be applied to an electrical appliance, such as a clothes drying machine, or an appliance designed to heat up a mass of water.

**[0005]** A clothes drying machine, such as a tumble dryer or a so-called washer-dryer, using a heat pump arrangement installed therein, is largely known to be provided with an automatic system for drying wet clothes from a washing operation. During a drying cycle, the process medium is circulated in a particular aeraulic circuit conditioning itself with the closed-loop circuit of the heat pump device, until the clothes are fully dried.

**[0006]** As is also generally known in the art, a heat pump-assisted appliance designed to heat up a mass of water, such as a boiler, a water heater, or the like, includes a heat pump device incorporating a water container, in which (or in contact with which) there is arranged the condenser. As a result, the temperature of the water mass, which is in close contact with the condenser, is caused to increase due to the same condenser overheating during operation.

**[0007]** In each one of the above-cited kinds of heat pump-assisted electric appliances, the high-temperature heat-energy using function is represented by a load of water, as constituted by the water contained in the wet clothes to be dried and the mass of water contained in the container, respectively. In a respective initial process step of both the clothes drying cycle and a water mass heating cycle, such load of water shall therefore by brought up to an operating temperature value, within a definite time to thermal stabilization.

**[0008]** However, the specific heat of water is generally known to be very high and, for the matter, higher than that of most other substances; as a result, the need arises for quite considerable an amount of heat (thermal energy) to be supplied to the load of water before the temperature thereof can be caused to rise to the required operating value. Therefore, the above-cited time to thermal stabilization turns out as being relatively long and this does of course not fail to correspondingly affect the entire cycle time.

**[0009]** In view of cutting the total cycle time - and for a given, unaltered power rating of the compressor and/or an unaltered efficiency of the condenser and/or the evaporator - it is a known practice to make use of an auxiliary electric heater, generally a resistance-type electric heating element.

**[0010]** This electric heating element is installed in the heat pump-assisted electric appliance in view of boosting the heat energy that is available for being transferred to the load of water, so as to more promptly bring the same load of water up to the desired operating temperature.

**[0011]** For example, it is a known practice to have a heat pump assisted clothes drying machine provided with an aeraulic circuit that is in turn provided with electric heating elements aimed at supplying supplementary heat energy to the process medium and, as a result, the water load (heat energy using function). Again, it is a known practice to provide a heat pump assisted machine for heating up a mass of water with a water container, in which there are provided electric heating elements submerged in the mass of water so as to supply supplementary heat energy to the water load (heat energy using function) directly.

**[0012]** However, an advantage deriving from the use of supplementary electric heating elements is to the detriment of the safety of the heat pump assisted electrical appliance, which has in fact to be properly equipped with special safety provisions in this case. Furthermore, the supplementary heat energy is supplied either to the process medium or directly to the heat-energy using function, as the case may be, and such supplementary heat energy cannot be boosted (COP) by way or in the course of a vapour-compression refrigeration cycle.

**[0013]** Described in the Japanese patent application no. 2001108311 is an auxiliary electric heater, the operation of which is based on the largely known principle of electromagnetic induction, as applied to a refrigeration apparatus to the purpose of defrosting the evaporator thereof.

**[0014]** Such electric heater is provided by coating or covering a portion of the piping of the closed-loop circuit of the heat pump device, comprised between an expansion valve and an evaporator, with either a cylinder of ferromagnetic material, such as for instance an iron pipe, or thin sheets of ferromagnetic material, such as for instance iron foils. Around the ferromagnetic material there is wound a lead wire so as to form a coil. This coil is connected to an electric circuit supplied by a high-frequency current generator so as to promote the formation of hysteresis losses and eddy currents in the ferromagnetic material, in such manner as to determine an energy dissipation in the form of heat. Part of this heat developing in the ferromagnetic material is transferred by heat conduction to said portion of the piping, which is in turn able to transfer heat to the part of refrigerant medium being each time in contact with an inner surface of said same piping portion.

**[0015]** However, a remaining part of the heat generating in the ferromagnetic material is wasted through surfaces - of both the ferromagnetic material and the piping portion itself - that are not in contact with any refrigerant medium, so that they are not able to transfer any heat thereto, i.e. to heat up such medium.

**[0016]** Furthermore, with reference to the electric heater in the switched-off state thereof, the pre-heated refrigerant medium upstream to the evaporator consequently takes up, i.e. absorbs from the cold environment a smaller amount of heat, wherein such amount of heat may even be equal to nil when such medium reaches the evaporator. The evaporator would in fact act as a heatsink to dissipate the energy that has just been introduced thereinto.

**[0017]** It is therefore an object of the present invention to do away with such drawbacks of prior-art solutions by providing a heat pump device provided with an electric heater adapted to directly supply heat energy to the refrigerant medium so as to cut the total cycle time of the heat pump assisted electric appliance.

**[0018]** A further, equally important purpose of the present invention is to provide a heat pump device provided with an electric heater that is capable of being manufactured with the use of readily available equipment, tools and techniques.

**[0019]** Some advantageous developments and improvements are set forth in the appended claims, wherein it may be appropriate to put a special emphasis on the fact that the refrigerant medium reaches back into the compressor in a full vapour state. As a result, the heat pump device is particularly well suited to an operation at low environmental temperatures.

**[0020]** According to the present invention, the above-indicated aims, features and advantages, along with further ones that will become apparent from the following disclosure, are reached in a heat pump clothes drying machine incorporating the characteristics as defined and recited in the appended claims.

**[0021]** Features and advantages of the present invention will anyway be more readily understood from the description of exemplary embodiments thereof that is given below by way of non-limiting example with reference to the accompanying drawings, in which:

- Figure 1 is a schematic view of an electric heater according to the present invention;
- Figure 2 is a block diagram illustrating schematically a circuit for the generation of variable electric oscillations;
- Figure 3 is a schematic view of a heat pump device as applied to a clothes drying machine according to a first embodiment of the present invention;
- Figure 4 is a schematic view of the heat pump device as applied to a machine for heating up a mass of water according to the first embodiment of the present invention; and
- Figure 5 is a schematic view of a heat pump device as applied to a machine for heating up a mass of water according to a second embodiment of the present invention.

**[0022]** With reference to the above-listed Figures, a heat pump device according to the present invention comprises at least a closed-loop circuit circulating a refrigerant medium as it undergoes the steps of a vapor-compression refrigeration cycle, wherein said closed-loop circuit is supplied by at least a compressor 40; 140 and comprises at least a condenser 42; 142, at least an expansion valve 44; 144, at least an evaporator means 46; 146, and at least an electric heater 20; 120.

**[0023]** With special reference to solely Figure 1 now, the electric heater 20; 120 comprises a fluid-tight casing 22, in which there can be defined an interior, and which is for example formed of a metal or polymeric material in the manner of a cylindrical reservoir developing in the longitudinal direction thereof.

**[0024]** The casing 22 is provided with a plurality of attachment end portions, e.g. two of them. A first one 24 of such attachment end portions and a second one 26 of such attachment end portions of the casing 22 terminate with a respective sleeve (not shown) adapted to be connected in a fluid-tight manner to a piping (not shown), in particular the piping of the closed-loop circuit of the heat pump device, which is in turn provided with complementary connecting means.

**[0025]** Thereinside, the casing 22 contains at least a heating element 28. This heating element 28 may be formed of any electrically conducting mass whatsoever, such as a metal material, as processed for instance into granules and/or micro-wires and/or micro-spheres, or the like. Or, in a modified embodiment of the present invention, the heating element 28 may be in the form of metal protrusions extending inwards in the casing 22 from an inner surface thereof. In all cases, the heating element 28 at least partially fills the casing 22, however without obstructing a passage, through which a fluid, such as in particular the refrigerant medium, is able to flow, and which connects the attachment end portions 24, 26 with each other.

**[0026]** An electrically conducting wire is wound around the casing 22 so as to form a coil 32 therearound. The coil 32 is provided with contact terminals so as to be able to be electrically connected to a circuit 34 for generating a variable electric oscillation.

**[0027]** With reference to Figure 2, the circuit 34 for generating variable electric oscillations substantially comprises a direct-current power supply 35 for supplying power to a high-frequency oscillator 36, such as for instance a square-wave oscillator, and to a power driver 37, such as for instance one or several bipolar transistors, one or several MOSFETs, one or several IGTBs, or the like, connected in a cascaded arrangement relative to the oscillator 36. The power supply 35 may be comprised of a cascade connection of a transformer, a rectifier and a voltage regulator, or any other power-supply circuit adapted to supply power from the mains, such as for instance a switching power supply in a flyback configuration.

**[0028]** What said circuit 34 for generating a variable electric oscillation and said coil are required to do is to produce a magnetic flux variation on a surface of the heating element 28, so that eddy currents will generate therewithin. In said heating element 28, these eddy currents give rise to an energy dissipation effect in the form of heat, i.e. thermal energy.

**[0029]** The energy that can be transferred to the refrigerant medium by means of the electric heater 20; 120 is controllable in a variety of manners generally known as such in the art, such as for instance by acting on the form of the wave driving the power driver 37.

**[0030]** The electric heater 20; 120 is connected in a portion of the closed-loop circuit that is comprised between the evaporator means 46; 146 and the compressor 40; 140, and, when switched on, the refrigerant medium fills up the casing 22, thereby submerging the heating element 28 that provides a relatively large wetted periphery. Owing to the construction peculiarities of the electric heater 20; 120, the refrigerant medium is able to flow into the casing 22 while flushing the heating element 28. As a result, the refrigerant medium can take up, i.e. adsorb an amount of heat by heat conduction directly from the heating element 28, which provides a considerably large heat-exchange surface within a very short distance as compared with the size of an ordinary evaporator means 46.

**[0031]** The effects of such heating up of the refrigerant medium in the portion of closed-loop circuit, in which the electric heater 20; 120 is installed, shall be now explained in greater detail on the basis of some application examples.

**[0032]** Figure 3 is a schematic view of the heat pump device according to the present invention, as applied to a clothes drying machine. This heat pump device conditions itself with an aeraulic circuit of the clothes drying machine provided to give rise to a continuous circulation of a process medium, such as for instance drying air, by means of a fan 52. The thus circulated drying air is blown through the clothes being handled to dry within a drum (not shown), the evaporator means 46 and the condenser 42.

**[0033]** The electric heater 20, which - with reference to the flow direction of the refrigerant medium - is inserted in a portion of the closed-loop circuit located downstream from the evaporator means 46 and upstream to the compressor 40, may be activated, i.e. switched on, in order to supply heat energy directly to the refrigerant medium so as to increase the heat energy being stored up in the evaporator means 46, thereby assisting the heat pump device in accelerating.

**[0034]** In fact, if a comparison is made - as it will be made from now on, actually - with an operation with the electric heater 20 in a switched-off condition, the refrigerant medium can be noticed to expand to a greater extent in the compressor 40. This brings about a more intensive compression work, which translates into a higher temperature of the refrigerant medium leaving the compressor 40. In other words, the heat energy supplied by the electric heater 20 is amplified by a coefficient of performance (COP) of the heat pump device.

For the temperature of the refrigerant medium to be kept under control, the electric heater 20 may be inserted in a feedback loop that further comprises a control unit 38 and a temperature sensor 50. The sensor may detect the temperature of the refrigerant medium at the outlet of the compressor 40 and compare it with a reference temperature. The outcome of such comparison is sent to the control unit 38, which can perform a temperature regulation by acting on the electric heater 20 accordingly.

**[0035]** When the electric heater 20 is switched on, the refrigerant medium therefore reaches up to the condenser 42 at a higher temperature.

As a result, the drying air that flushes the condenser 42 can itself reach a higher temperature and, therefore, can transfer a greater amount of heat to the water contained in the clothes to be dried (water load) so as to cause it to rise to an effective operating temperature within a shorter time. Accordingly, a time to thermal stabilization is cut for the benefit of a shorter overall drying cycle time, which in fact is in turn reduced.

**[0036]** Shown schematically in Figure 4 is a heat pump device according to the present invention as applied to a machine for heating up a mass of water. The heat pump device incorporates a container 60 due to contain the water in which there is submerged the condenser 42, whereas the evaporator means 46 is arranged to be flushed by a flow of air circulated by a blower 52.

**[0037]** In a similar way as in the case of the clothes drying machine, the electric heater 20, inserted in a portion of the closed-loop circuit comprised between the evaporator means 46 and the compressor 40, may be activated, i.e. switched on, in order to supply heat energy directly to the refrigerant medium so as to increase the heat energy being stored up in the evaporator means 46, thereby assisting the heat pump device in accelerating.

**[0038]** In fact, if a comparison is made also in this case - as it will be made from now on, actually - with an operation with the electric heater 20 in a switched-off condition, this brings about a more intensive compression work, which translates into a higher temperature of the refrigerant medium leaving the compressor 40.

**[0039]** The temperature of the refrigerant can be controlled by inserting the electric heater 20 in a feedback loop that further comprises a control unit 38 and a temperature sensor 50 adapted to detect the temperature of the refrigerant medium at the outlet of the compressor 40.

**[0040]** When the electric heater 20 is switched on, the refrigerant medium therefore reaches up to the condenser 42 at a higher temperature. As a result, the condenser 42 can transfer a greater amount of heat to a mass of water 62 contained in the container 60 (water load) so as to cause it to rise to an effective operating temperature within a shorter time. Accordingly, a time to thermal stabilization is cut for the benefit of a shorter overall drying cycle time, which in fact is in turn reduced.

**[0041]** Shown schematically in Figure 5 is a heat pump device according to a second embodiment of the present invention as applied to a machine for heating up a mass of water. In this second embodiment, the heat pump device comprises an evaporator means 146 that is provided integrally with the electric heater 120, all other parts of the closed-loop circuit remaining unaltered.

**[0042]** Therefore, when leaving an expansion valve 144, the refrigerant medium enters the electric heater 120 in a liquid state. When the electric heater 120 is actively operating, the refrigerant medium can vaporize in a first portion of the casing of the electric heater 120. As a result, such first portion of the casing acts as the actual evaporator means 146.

**[0043]** The other parts and the operation of the machine for heating up a mass of water are the same as in the first embodiment described afore.

**[0044]** Fully apparent from the above description is therefore the ability of the heat pump device according to present invention to effectively reach the aims and advantages cited afore by in fact providing a heat pump device provided with an electric heater 20; 120 that is adapted to supply heat energy directly to the refrigerant medium to thereby ensure an improved performance in terms of overall cycle time of the heat pump assisted electric appliance (amplification - COP).

**[0045]** It shall be appreciated that the inventive heat pump device as described above may be subject to a number of modifications and may be embodied in a number of different manners, or can be used in a number of different applications, without departing from the scope of the present invention.

**[0046]** For instance, the heating element 28 flooded by the refrigerant medium may be formed of at least one resistance wire or element enclosed in a sealed sheath capable of being connected to a power-supply circuit, for instance via appropriate fluid-tight ducts.

**[0047]** It shall be further appreciated that all afore-described embodiments and related variants may be implemented either individually or in any possible combination thereof.

## Claims

1. Heat pump device comprising at least one closed-loop circuit supplied by at least one compressor (40; 140) and comprising at least one evaporator means (46; 146) and at least one electric heater (20; 120), said closed-loop circuit being adapted to circulate a flow of refrigerant medium, **characterized in that** the electric heater (20; 120) is adapted to transfer thermal energy to the refrigerant medium in a portion of the closed-loop circuit located downstream from the evaporator means (46; 146) and upstream to the compressor (40; 140).

2. Heat pump device according to claim 1, wherein the electric heater (20, 120) comprises at least a heating element (28) adapted to be flushed by the refrigerant medium, said heating element (28) being submerged in a flow of said refrigerant medium.

3. Heat pump device according to claim 1, wherein the heating element (28) is adapted to be subject to the formation of induced eddy currents that dissipate energy in the form of heat.

4. Heat pump device according to claim 2, wherein the electric heater (20; 120) comprises a fluid-tight casing (22) containing the heating element (28) and a coil (32), said coil (32) being wound on said casing (22).

5. Heat pump device according to any of the preceding claims, wherein the evaporator means (46; 146) is formed at least partially by the electric heater (20; 120).

6. Heat pump device according to any of the preceding claims, wherein the coil (32) of the electric heater (20; 120) is connected to a circuit (34) for generating a variable electric oscillation, which comprises a power supply (35), an oscillator (36) and a power driver (37), said circuit (34) being adapted to bring about a variable electromagnetic field flooding the heating element (28).

7. Heat pump device according to any of the preceding claims, wherein the electric heater (20; 120) is inserted in a feedback loop comprising a control unit (38; 138) and a temperature sensor (50; 150), said feedback loop being adapted to regulate a temper-

ature of the refrigerant medium at an outlet of the compressor (40; 140).

**8.** Heat pump assisted clothes drying machine, **characterized in that** it comprises the heat pump device as defined in any of the preceding claims 1 to 7.

**9.** Heat pump assisted appliance for heating up a mass of water, **characterized in that** it comprises the heat pump device as defined in any of the preceding claims 1 to 7.

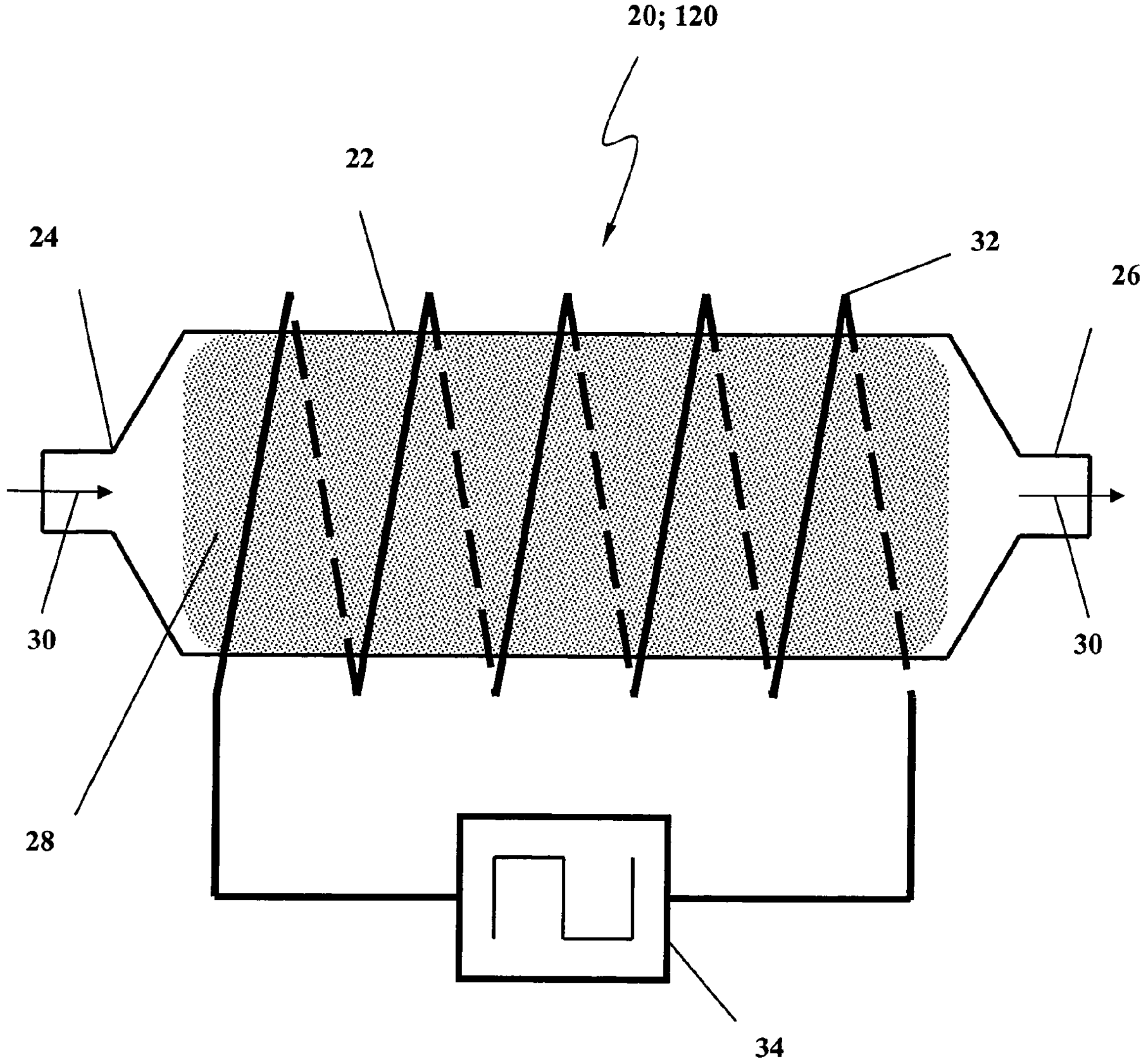


Fig. 1

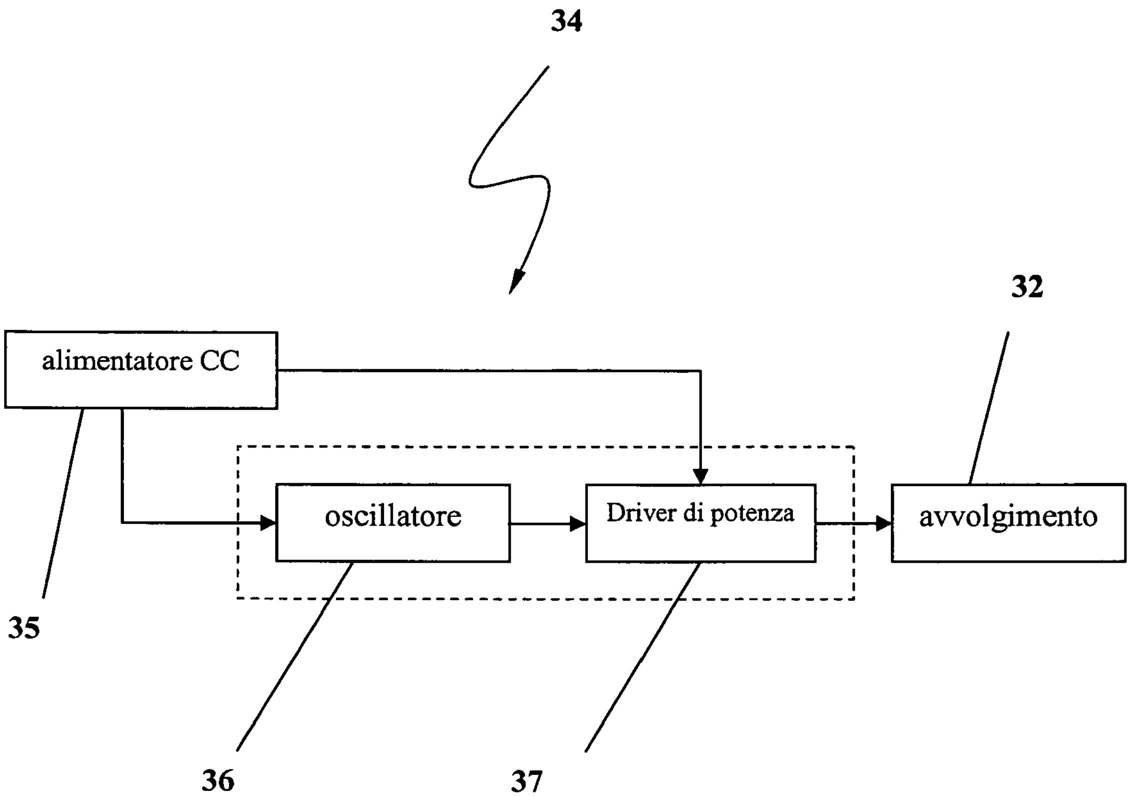
34
32
alimentatore CC
oscillatore
Driver di potenza
avvolgimento
35
36
37

Fig. 2

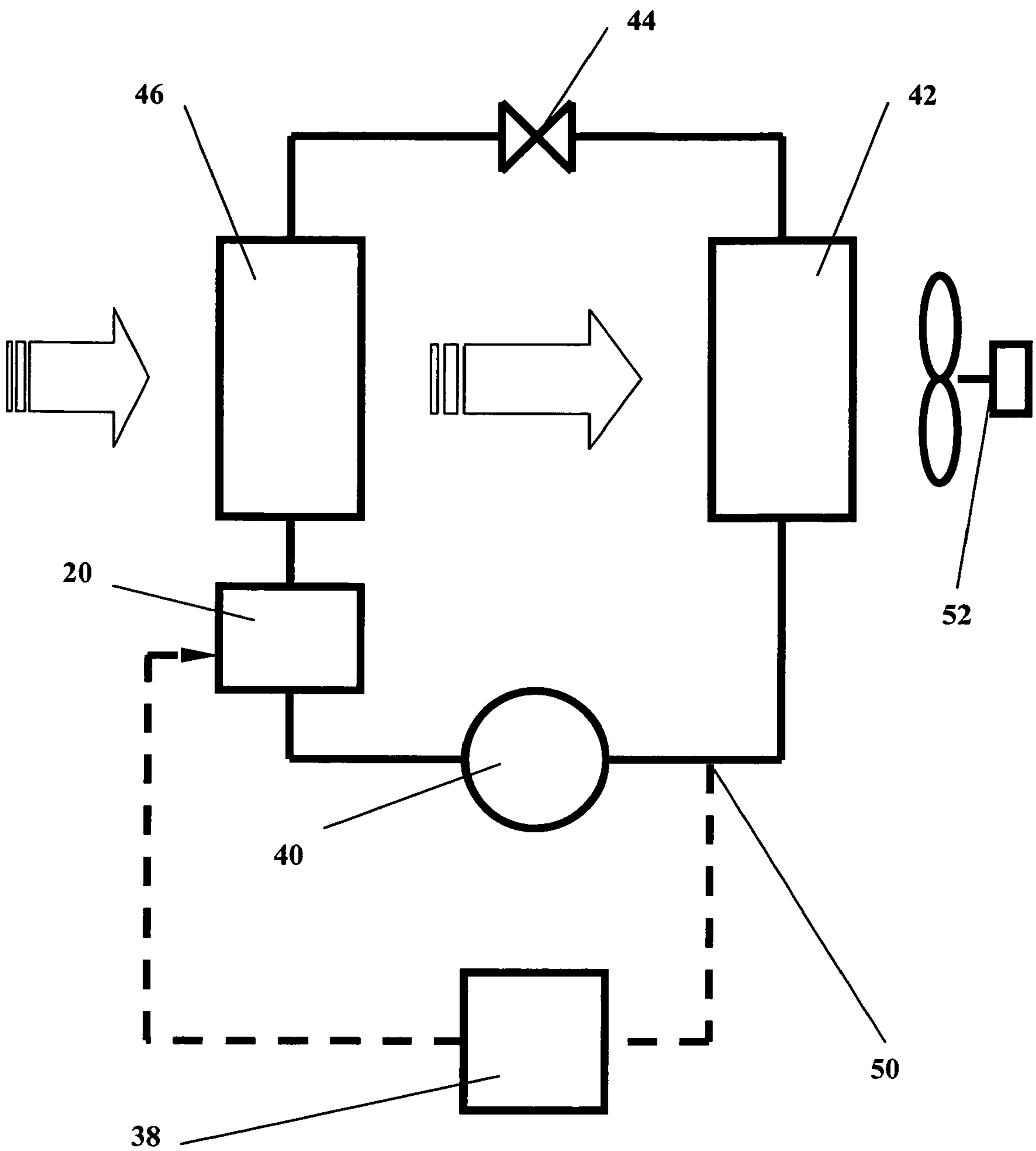


Fig. 3

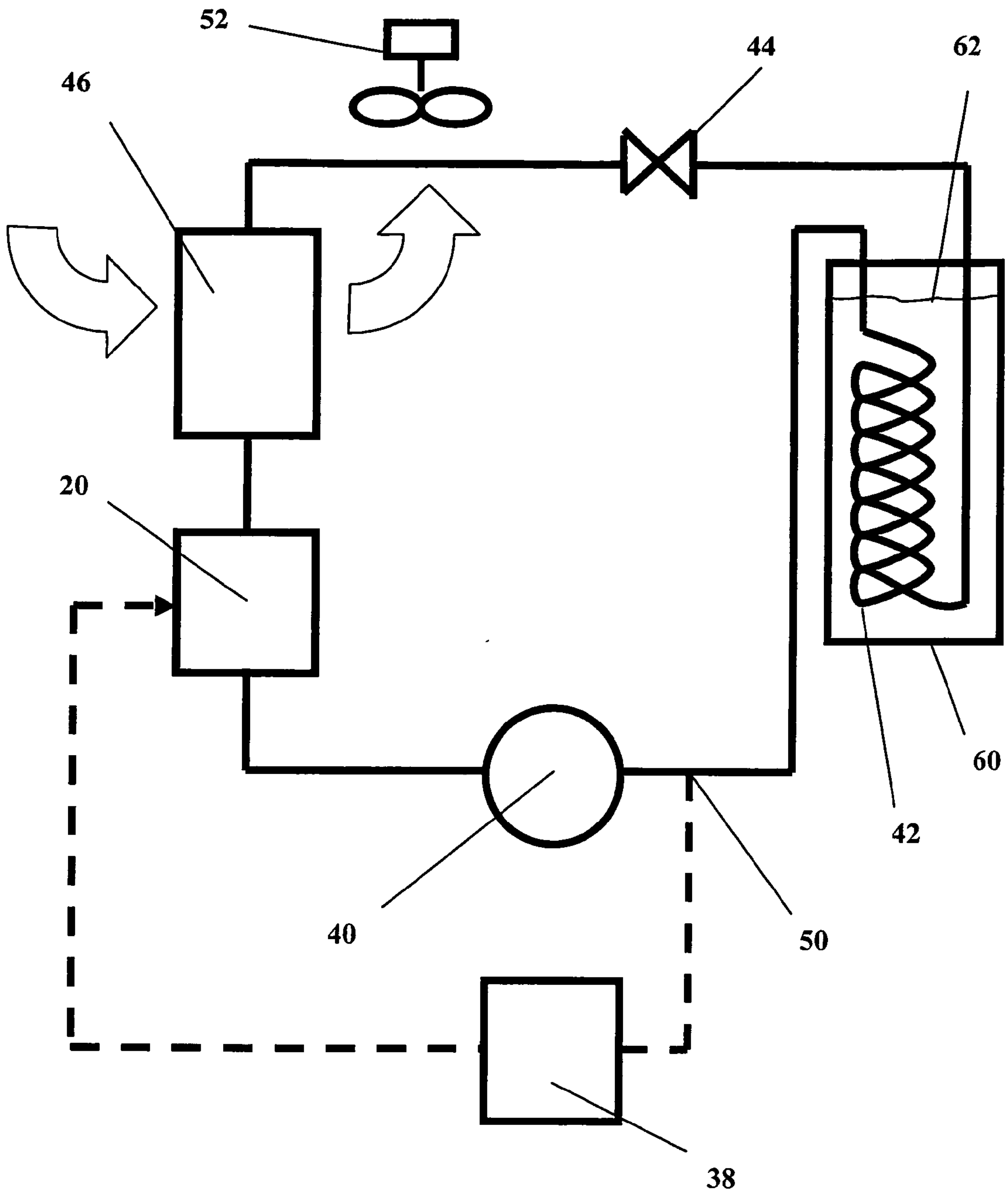


Fig. 4

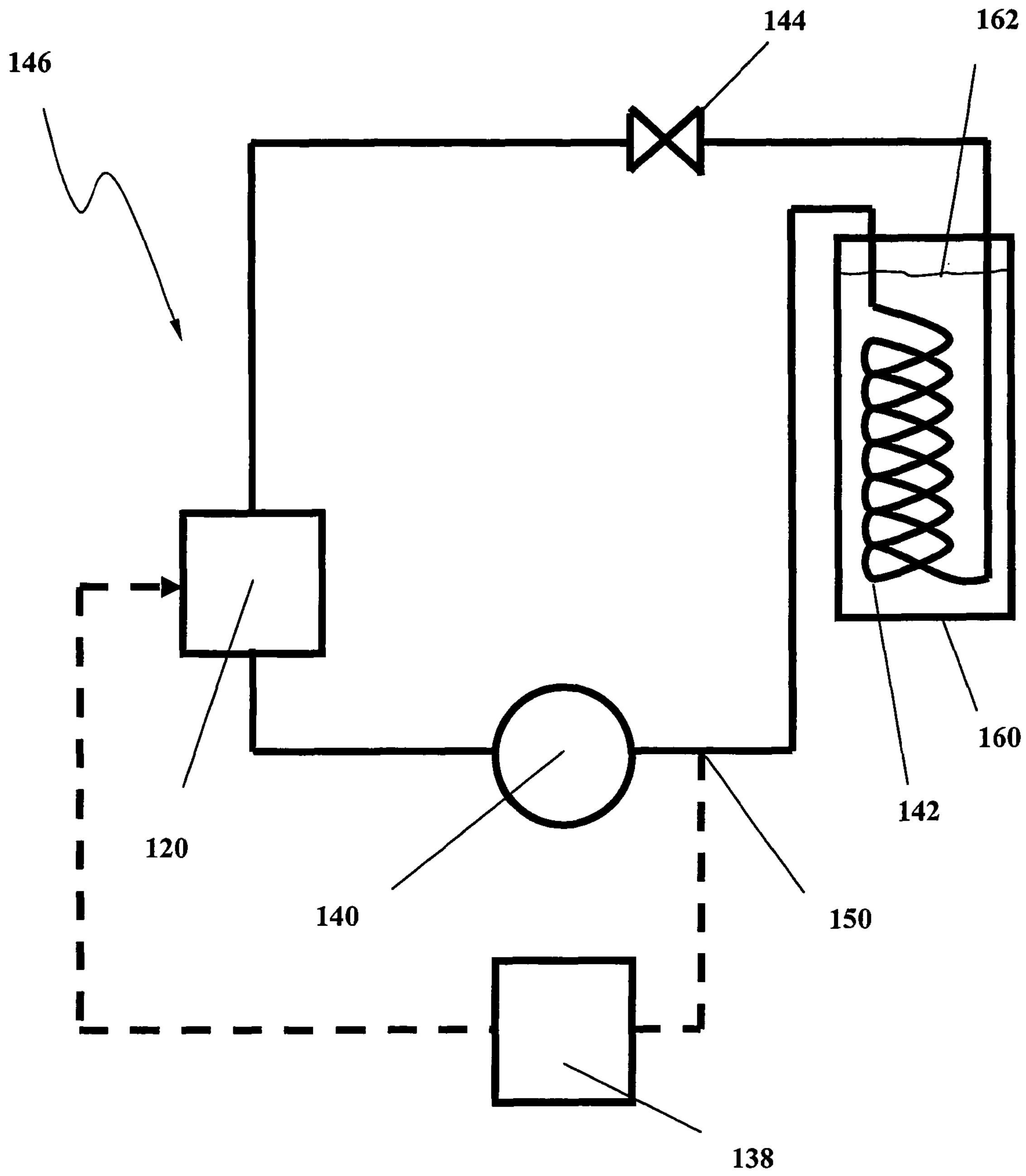


Fig. 5

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# EUROPEAN SEARCH REPORT

Application Number
EP 08 42 5513

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The present search report has been drawn up for all claims

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| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 12 November 2008 | Ritter, Christoph |

CATEGORY OF CITED DOCUMENTS

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