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(54) **Apparatus including a heat pump and method to operate an apparatus including the heat pump**

(57) The invention relates to a method to operate an apparatus (1) including a heat pump (30) to warm up or to cool down a process medium. The apparatus (1) includes a heat pump (30) having a refrigerant circuit (38) in which a refrigerant can flow, said refrigerant circuit (38) including a first heat exchanger (31) where the refrigerant is cooled off, a second heat exchanger (32) where the refrigerant is heated up, a compressor (33) to pressurize and circulate the refrigerant through the refrigerant circuit, said compressor (33) including a lubricant, and a pressure-lowering device (34); said first and/or second heat exchanger being apt to perform heat exchange between said refrigerant flowing in said refrigerant circuit (38) and said process medium. The method includes: monitoring the temperature and/or pressure value of said refrigerant in a location (35a,35b,35c,35d) within said refrigerant circuit (38); and determining lubricant trapping within said refrigerant circuit (38) on the basis of said temperature and/or pressure values versus time.

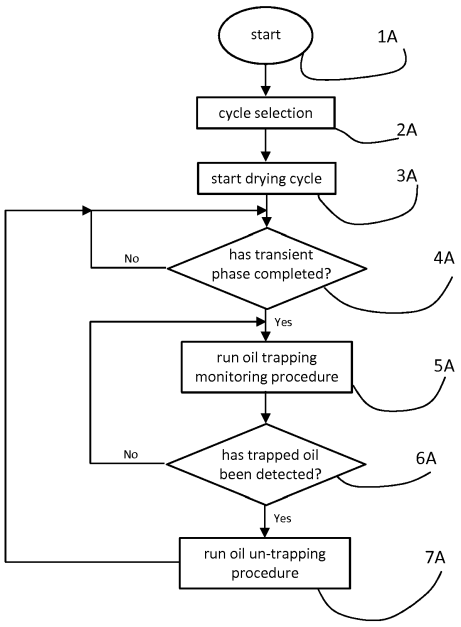


Fig. 13

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Description

Technical field

[0001] The present invention relates to an apparatus including a heat pump and a method to operate such an apparatus. The heat pump includes a refrigerating circuit in which lubricant leaking from a compressor might be present and trapped, causing a reduction in the heat pump efficiency. The apparatus and the method of the invention overcome the above mentioned problem.

Background art

[0002] Most dryers comprise a rotating drum called a tumbler through which heated air is circulated to evaporate the moisture from the load. The tumbler is rotated to maintain space between the articles in the load. In case of washer dryers, the drum is located inside a tub for the washing cycles.

[0003] Known laundry dryer includes two categories: condense laundry dryers and vented laundry dryers. Dryers of the first category circulate air exhausted from the drum through a heat exchanger/condenser to cool the air and condense the moisture; they subsequently recirculate the air back through the drum. Dryers of the second category draw air from the surrounding area, heat it, blow it into the drum during operation and then exhaust it through a vent into the outside. The present invention is applicable to both of the above mentioned categories.

[0004] Heat pump technology has been recently applied to laundry dryer in order to enhance the efficiency in drying clothes. More generally, heat pumps have been applied nowadays to a plurality of different appliances, such as dish washers, washing machines, washer-dryers, tumble dryers, air conditioners and refrigerators to enhance the efficiency of their functioning.

[0005] In traditional heat pump dryer, the heating system comprises a refrigerating circuit in which humid hot air coming from the drum is fed so that, by means of a refrigerating fluid, the humidity contained in the hot air is made to condense and is therefore discharged, whilst hot dry air is again fed to the drum. More in detail, the air, moved by a fan, passes through the drum removing water from wet clothes, and then it is cooled down and dehumidified in a heat pump evaporator and heated up in a heat pump condenser to be reinserted into the drum. In order to function, the heat pump includes the refrigerant fluid with which the air is in thermal exchange, and the refrigerant is compressed by a compressor, condensed in the condenser, laminated in an expansion device and then vaporized in the evaporator.

[0006] Generally, in the present field, the compressor of the refrigerating circuit of a heat pump located in an appliance includes a lubricant, usually a lubrication oil, to promote the safe hydrodynamic lubrication inside the compressor by creating a thin film within the moving parts of the same, such as pistons, shaft, bearings, etc. In this way the wear of the moving parts due to the friction is reduced. The lubricant oil also can also contribute to cool the electric motor of the compressor. This effect is important mainly in semi-hermetic or hermetic compressors the heat exchange with the environment are very low.

[0007] In the dryer of EP1405946, a rotary compressor is used that constitutes together with the evaporator, the expansion valve and the gas cooler connected in an annular shape a refrigerant circuit. The rotary compressor is an internal middle pressure multistage compression type which uses CO_2 as a refrigerant. The rotary compressor comprises a cylindrical airtight container, and a rotary compression mechanism section which is constituted of a first rotary compression element (first stage) and a second rotary compression element (second stage) driven by a rotary shaft. The mechanical parts of the compressor are lubricated by oil fed form a reservoir by means of relevant holes to the suitable part of the compressor. The moisture contained in the air coming from the drying chamber is condensed to be discharged by the evaporator.

[0008] US20050086827 describes a clothes drying machine provided with a heating pump constituted of a compressor, a heating coil, an expansion valve, and a cooling coil and capable of circulating a heat exchange medium. The things to be dried are dried by the high-temperature air heated by the heating coil, and moisture evaporated from the dried things is coagulated and discarded by the cooling coil. The air passed through the radiator is circulated upwards from below, and the refrigerant flowing in the radiator is circulated downwards from above. When the refrigerant is circulated downwards from above in the radiator, oil contained in the refrigerant discharged from the compressor is not easily accumulated in the radiator, and the oil is smoothly returned to the compressor.

[0009] JP 2005-061348 discloses a sealed compressor of inexpensive structure and less oil discharge quantity. In this sealed compressor, a motor part having a cooling medium passage at an outer circumferential part is provided at an upper part in a sealed container, and a compression mechanism part and lubricating oil are contained at a lower part. The sealed container is formed of a cylindrical container sealed at one end, and an upper cover part. In the upper cover part, a glass terminal to supply external power to the motor part, and a discharge pipe to let compression gas at the compression mechanism part out of the sealed container are provided. The upper cover part of the sealed container is formed to be roughly spherical. The glass terminal is installed close to the center of the upper cover part. The discharge pipe is provided at an angle along a spherical surface of the upper cover part, that does not coincide with the cooling medium passage for the circumferential position.

Summary of the invention

[0010] The present invention is relative to an apparatus

including a heat pump and a method to operate such an apparatus. The configuration and construction of the apparatus of the invention is realized in order to discover and remedy to lubricant trapping within the refrigerant circuit of the heat pump.

[0011] Examples of apparatuses including a heat pump are for example appliances such as fridges, air conditioners, washing machines, washer-dryers, laundry dryers, dish washers, and the like.

[0012] With the terms "downstream" and/or "upstream", in the following a position with reference to the direction of the flow of a medium, such as a fluid, inside a conduit is indicated. Moreover, in the present context, the terms "vertical" and "horizontal" are referred to the positions of elements with respect to the apparatus' position in its normal installation or functioning. In all mentioned appliances, a heat pump is used to heat up or cool down a process medium which is used in a treating chamber, as it will be better explained below.

[0013] The heat pump of the apparatus includes a refrigerant circuit in which a refrigerant can flow and which connects via piping a first heat exchanger or condenser, a second heat exchanger or evaporator, a compressor and a pressure-lowering device. The refrigerant circuit can be functionally divided in two portions, a high pressure portion which is the portion of the refrigerant circuit connecting the compressor to the pressure lowering device via the condenser, and a low pressure portion which is the portion of the circuit connecting the pressure-lowering device back to the compressor via the evaporator. The term "high" and "low" are relative terms and their meaning is that the pressure of the refrigerant in the "high pressure" portion is higher than in the "low pressure" portion. The refrigerant is pressurized and circulated through the system by the compressor. On the discharge side of the compressor, the hot and highly pressurized vapor is cooled in the first heat exchanger, called the condenser, until it condenses into a high pressure, moderate temperature liquid. The condensed refrigerant then passes through the pressure-lowering device such as an expansion device, e.g. a choke, a valve or a capillary tube. The low pressure liquid refrigerant then enters another (second) heat exchanger, the evaporator, in which the fluid absorbs heat and evaporates. The refrigerant then returns to the compressor and the cycle is repeated.

[0014] In some embodiments, in the evaporator and condenser, the refrigerant may also not be subject to a phase transition. In general, in the following, evaporator and condenser, due to their function, will also be called heat exchangers.

[0015] In case of a refrigerating appliance, including a process medium such as air and a refrigerator casing to be cooled (which is the treating chamber), the circulating refrigerant enters the compressor as low-pressure vapor. The vapor is compressed and exits the compressor as high-pressure superheated vapor. The superheated vapor travels under pressure through the condenser, which is passively cooled by exposure to air in a room where the refrigerator is located. The condenser cools the vapor, which liquefies. As the refrigerant leaves the condenser, it is still under pressure but is now only slightly above room temperature. This liquid refrigerant is forced through the pressure -lowering device to an area of much lower pressure. The sudden decrease in pressure results in evaporation of a portion of the liquid. This cold and partially vaporized refrigerant continues through the coils or tubes of the evaporator, where the refrigerant completely vaporizes, drawing further latent heat from process medium (air) present in the refrigerator casing. This cooled process medium (air) is present in the refrigerator or freezer compartment, and so keeps the refrigerator casing cold. Note that the cool air in the refrigerator or freezer is still warmer than the refrigerant in the evaporator. Refrigerant leaves the evaporator, now fully vaporized and slightly heated, and returns to the compressor inlet to continue the cycle.

[0016] Analogously, in an air conditioner the refrigerant is pumped into the evaporator located in the compartment to be cooled (the treating chamber), where the low pressure causes the refrigerant to evaporate into a vapor, taking heat with it from the air (the process medium). At the opposite side of the cycle is the condenser, which is located outside of the cooled compartment (like in the exterior), where the refrigerant vapor is cooled, condensing the refrigerant into a liquid, thus rejecting the heat previously absorbed from the cooled space.

[0017] As seen in the previous examples, the process medium, which in both examples is air, is cooled by the evaporator of the heat pump.

[0018] Alternatively, in appliances such as a dryer, a washer-dryer, a washing machine, or a dish washer, a process medium such as air or water, is warmed up by the condenser and it is then used also in the treating chamber.

[0019] As an example, a traditional heat pump dryer includes a drying chamber (the treating chamber), such as a drum, in which the load, e.g. clothes, to be dried is placed. The drying chamber is part of an air process circuit, in particular a closed-loop circuit in case of a condensed dryer or an open circuit in case of a vented dryer, which in both cases includes an air conduit for channeling a stream of air to dry the load. The process air circuit is connected with its two opposite ends to the drying chamber. More specifically, heated dry air is fed into the drying chamber, flowing over the laundry, and the resulting humid cool air exits the same. The humid air stream rich in water vapor is then fed into the evaporator of the heat pump, where the moist warm process air is cooled and the humidity present therein condenses. The resulting cool dry air is then either vented outside the dryer in the ambient where the latter is located or it continues in the closed-loop circuit. In this second case, the dry air in the process circuit is then heated up before entering again in the drying chamber by means of the condenser of the heat pump, and the whole loop is repeated till the end of the drying cycle. Alternatively, ambient air enters into the

drum from the ambient via an inlet duct and it is heated up by the condenser of the heat pump before entering the drying chamber.

[0020] In the refrigerant circuit of such a dryer, the refrigerant undergoes a phase transition from the liquid to the vapor phase at the evaporator due to the heat exchange with the warm process air exiting the drying chamber. The evaporated refrigerant is then supplied via the compressor to the condenser, which functions as seen above as a heat source for the dryer and in which the refrigerant condenses again, heating up the process air before the latter is introduced into the drying chamber.

[0021] The same structure is present in a washing machine, where the process medium, e.g. water, is warmed up by the condenser and flows into the washing chamber (the treating chamber) where the load is washed, or in a dish washer machine, where again the process water is warmed up to wash the dishes in the washing chamber.

[0022] The compressor of any of the above described appliances pressurizes and circulates the refrigerant through the whole refrigerant circuit, and includes an inlet pipe for the introduction into a suction inlet (the suction inlet substantially identifies the location where the inlet pipe connects into the compressor) of refrigerant, which is reaching the compressor in the gaseous phase, and an outlet pipe for the discharge of the compressed refrigerant which exits into the circuit as a gas, hotter and having an higher pressure than at the inlet. The compressor is preferably of the hermetically sealed type including an air-tight container and it is lubricated by a lubricant, such as oil, in order to reduce the internal wear of the moving parts, such as a sucking, compressing and discharging elements, and improve the cooling of the same. For example, the compressor can be a single-stage or multi-stage rotary compressor. Preferably, the compressor includes a motor which has a variable speed.

[0023] Preferably, an oil storage is provided at the lower part of the container for reserving lubricant oil. The lubricant can be exhausted via the outlet pipe into the piping of refrigerant circuit during normal functioning, due to fluid communication inside the compressor between the different components of the same. Thus, a certain amount of lubricant may flow through the piping of the refrigerant circuit together with the refrigerant itself.

[0024] It is to be understood that the refrigerant circuit does not include the components already described, i.e. the compressor, the heat exchangers and the expansion devices, only, but it can also include additional components, such as additional condenser(s) which is/are preferably located between the condenser and the expansion device, and/or additional evaporator(s), and/or internal heat exchangers, and/or gas liquid separator located upstream the inlet of the compressor in order to trap the liquid and to avoid the entrance of the same into the compressor itself .

[0025] Depending on the type of refrigerant used in the heat pump, the lubricant oil and the refrigerant can be mutually completely miscible so that the liquid phase has only one phase and a homogeneous solution is formed between the two fluids; or the two fluids can be partially miscible so that in some proportion, they do not form a solution, but two separate liquid phases with different composition are formed at defined pressure and temperature levels. In general, the solubility increases with the pressure and decreases with the temperature level and most commonly at the outlet of the compressor they form a solution. Finally, the lubricant oil and the refrigerant may be completely immiscible, in this case two different liquid phase are formed at any temperature, pressure and composition. For the typical refrigerants used in heat pumps, refrigerant and lubricant are partly miscible in most of the cases (i.e. about 90% of the refrigerants and lubricants are partially miscible), and therefore in the following only the second and third possibilities are considered, the first one of complete miscibility being not relevant for the present invention.

[0026] A consequence of the partial miscibility (or immiscibility) of the lubricant oil and the refrigerant is that along the refrigerant circuit the two fluids may separate and the fluid flowing in the pipes can be a mixture of refrigerant and some amount of lubricant in form of droplets. The lubricant in addition can be trapped in some parts of the circuit, in particular in those positions where, due to the thermodynamic conditions, oil droplets form and get stuck in the piping.

[0027] It is necessary, however, that the mechanical parts of the compressor always remain lubricated during its functioning, and it is thus preferred that the lubricant oil returns to the compressor, in order to always keep a certain amount of lubricant inside the same.

[0028] Moreover, the presence of the lubricant oil trapped in the heat exchangers and more in general in the pipes of the refrigerant circuit can affect the efficiency of the system, i.e. it hinders the heat exchange between the process medium and the refrigerant.

[0029] Applicants have thus realized that the trapping of the lubricant can negatively affects the thermal efficiency of the heat pump and also the proper functioning of the compressor.

[0030] Applicants have therefore implemented a new heat pump apparatus and a method to operate the same so configured to overcome the above mentioned problems.

[0031] However, the design choice of apparatus such as domestic appliances, in particular laundry dryers, washer-dryers, washing machines and dish-washers, is heavily constrained by the limited space available and the dimensions of the heat exchangers present in the same, therefore a proper design of the piping which promotes the return of the oil to the compressor and/or a proper placing of the compressor and heat exchangers within the apparatus' casing to avoid the oil trapping is not always possible. A different approach than the choice of a different design of the refrigerant circuit is therefore implemented.

[0032] First of all, Applicants have developed a method

and a device to detect that oil trapping is taking place within the refrigerant circuit.

[0033] For this purpose, Applicants have discovered that, when oil trapping takes place in a portion of the refrigerant circuit, it can cause an unstable behavior of the refrigerant temperature level and/or of the refrigerant pressure level during the functioning of the apparatus. With the term "unstable behavior", sudden variations (i.e. peaks and valleys, which are both called "extremes") of the temperature and/or pressure values in a short time interval it is meant. Preferably, the mentioned variations are from/to an upper limit to/from a lower limit, i.e. a sudden variation is a change between a maximum and a minimum of the temperature or pressure curve in a short time frame.

[0034] More in detail, Applicants have discovered that, monitoring the behavior of the temperature and/or the pressure of the refrigerant in specific portion(s) of the refrigerant circuit by a suitable sensor, as better detailed below, the oil trapping becomes visible due to the above mentioned unstable behavior of the pressure and/or temperature curve versus time. Therefore, analyzing the temperature and/or pressure fluctuations during the functioning of the apparatus of the invention, it is possible to easily detect the presence (or absence) of oil trapping in the circuit.

[0035] In a first aspect, the invention relates to a method to operate an apparatus including a heat pump apt to warm up or cool down a process medium , the apparatus including

- A heat pump having a refrigerant circuit in which a refrigerant can flow, said refrigerant circuit including a first heat exchanger where the refrigerant is cooled off, a second heat exchanger where the refrigerant is heated up, a compressor to pressurize and circulate the refrigerant through the refrigerant circuit, said compressor including a lubricant, and a pressure-lowering device; said first and/or second heat exchanger being apt to perform heat exchange between said refrigerant flowing in said refrigerant circuit and said process medium;

[0036] Said method comprising:

- Monitoring the temperature and/or pressure value of said refrigerant in a location within said refrigerant circuit; and

- Determining lubricant trapping within said refrigerant circuit on the basis of said temperature and/or pressure values versus time.

[0037] In a second aspect, the invention is relative to an apparatus including:

- A heat pump apt to warm up or cool down a process medium, said heat pump having a refrigerant circuit in which a refrigerant can flow, said refrigerant circuit including a first heat exchanger where the refrigerant is cooled off, a second heat exchanger where the refrigerant is heated up, a compressor to pressurize and circulate the refrigerant through the refrigerant circuit including a lubricant, and a pressure-lowering device; said first and/or second heat exchanger being apt to perform heat exchange between said refrigerant flowing in said refrigerant circuit and said process medium;

- A temperature and/or a pressure sensor located within said refrigerant circuit to detect a value of the temperature and/or the pressure of the refrigerant;

- A processing unit apt to receive a signal sent by said sensor based on said measured value; said processing unit being able to determine lubricant trapping on the basis of said measured value versus time.

[0038] According to the aforementioned aspects, the invention may include, in combination or alternatively, one or more of the following characteristics. Preferably, monitoring the temperature and/or pressure value includes identifying the extremes of said measured values versus time.

[0039] In other words, as said, the unstable behavior is recognizable by the presence of a plurality of extremes one following the others in a short time period in the temperature and/or pressure measured values versus time, plurality of values which form substantially a curve f(t). Therefore, in order to determine whether oil trapping is present or not in the refrigerant circuit, the extremes of the curve have first to be identified, in other words recognized by the processing unit.

[0040] More preferably, an oil trapping is considered to be present, according to different preferred embodiments of the invention, in the following cases:

- in a given time interval, more than a pre-set number of extremes in the temperature and/or pressure curve is present which hints that the unstable behavior takes place; or
- two extremes of the temperature and/or pressure curve are separated by a time interval shorter than a given time interval (i.e. the time distance between two maxima, or between two minima, or between a maximum and a minimum is below a given threshold), which also shows the onset of an instable behavior; or
- an high pass filter for filtering the signal of the measured values can be included in the dryer of the invention, which filters the substantially constant portion of the pressure and/or temperature curve during time. Oil trapping is considered to be present when the high frequency part of the pressure and/or temperature signal is substantially different from zero, i.e. the mean of the filtered values is above a defined

threshold.

[0041] Applicants have understood that the unstable behavior of the temperature and/or pressure curve, i.e. the appearance of the extremes and the oscillation between these minima and maxima, is due to the blockage of the refrigerant flow in the piping caused by the lubricant. In more details, temporary stops in the refrigerant flow takes place when the oil is trapped in the piping, and the stops are followed by momentary re-openings of the piping due to the consequent depressurization. This "stops and goes" of the refrigerant flow causes the unstable variations of pressure and/or temperature curve versus time described.

[0042] According to the invention, it is advantageous to locate the temperature and/or pressure sensor in that/those position(s) of the refrigerant circuit in which the observation of oil trapping is more likely to occur, i.e. where it is more likely that oil droplets form and stick to the piping walls, or where the unstable behavior is easier to detect, as clarified below. Applicants have found that the most favorable conditions for refrigerant-oil separation, thus for oil trapping of the oil droplets, or for the detection of the unstable behavior are present in those branches of the refrigerant circuit which are either:

- between the outlet of the evaporator and the inlet of the compressor, or
- Between the outlet of the condenser and the pressure-lowering device, or
- Between the outlet of the pressure-lowering device and the inlet of the evaporator, or
- located below or at the suction inlet level of the compressor, as better explained below.

[0043] A plurality of sensors, and not only one, located in one or more of the above positions is also envisaged in the present invention.

[0044] For a fixed refrigerant flow rate, the refrigerant speed is different in different points of the circuit according to the section of the pipes and the actual density of the refrigerant:

$$\dot{m} = \rho v A;\ A = \frac{\pi D^2}{4} \Rightarrow v = \frac{4\dot{m}}{\rho \pi D^2}$$

where $\dot{m}$ is the refrigerant flow rate, p is the refrigerant density, v is the refrigerant velocity, A is the pipe section and D the internal pipe diameter. As shown in the formula, the refrigerant velocity decreases in case of high density levels. In addition, the density is proportional to the pressure and inversely proportional to the temperature.

[0045] Between the outlet of the condenser and the inlet of the pressure-lowering device, the pressure is relatively rather high and the temperature is relatively rather low. This gives, due to the above explained formula, a rather high density of the refrigerant, and consequently a low velocity of the same. For this reason in this portion of the refrigerant circuit oil trapping is rather probable. In particular this branch of the refrigerant circuit is the one with the highest probability of oil trapping.

[0046] As known and said previously, in a heat pump system, the compressor is responsible of the circulation of the refrigerant circuit within the circuit itself and includes the inlet for the suction of the refrigerant fluid which is then compressed and exhausted by the output. In case a portion of the refrigerant circuit, i.e. some piping, is located at a vertical level which is lower than or equal to the vertical level defined by the location of the suction inlet of the compressor, the refrigerant cannot flow into the compressor by the simple application of gravity, on the contrary a force against gravity has to be exerted in order to transport the fluid inside the compressor. In these portions of the circuit located below or at the inlet vertical level, the refrigerant fluid has to flow faster than in other circuit's portions to avoid oil trapping, because oil trapping is more likely to occur, the lubricant cannot go back by gravity to the compressor. If such lower-than-or at-the-suction-inlet-level portions are present in the refrigerant circuit, a sensor is preferably placed correspondingly to check the pressure and/or temperature behavior of the refrigerant in that specific piping portion during the functioning of the apparatus.

[0047] The term "a vertical level lower than..." means the following: in the normal functioning of an apparatus, a vertical axis Z and also a (X,Y) plane perpendicular to the vertical axis which is the "ground" are defined. The suction inlet for suction of the refrigerant in the compressor is located, when mounted in the dryer, at a given height along the Z axis and it is substantially the entrance to the compressor chamber from which the inlet pipe extends. Considering a plane parallel to the (X,Y) plane and which intersect the Z axis in the point in which the suction inlet is located, it defines a "suction inlet level", so that all components of the refrigerant circuit which are located below the suction inlet plane are defined as being located below the "suction inlet vertical level".

[0048] In the fabrication of the apparatus of the invention, however, gravity is not the solution also for those portions of the refrigerant circuit which are only "slightly" above the suction inlet plane. Indeed, for a few cm above said plane, the effect of gravity is not strong enough to force the refrigerant to flow back to the compressor and again a high velocity of the refrigerant in those portions is desired in order to avoid oil trapping.

[0049] The other two mentioned branches of the circuit, i.e. between the outlet of the evaporator and the inlet of the compressor, and between the outlet of the pressure-lowering device and the inlet of the evaporator, the risk/probability of oil trapping is lower than in the other two regions above mentioned (i.e. between the outlet of the condenser and the pressure-lowering device and below the suction inlet of the compressor), however oil trapping is still possible due to the low temperature present (as

said oil trapping is more favorable where P is high and T is low, due to a reduced refrigerant density). In addition Applicants have observed that positioning a pressure and/or temperature sensor in these branches at lower pressure gives an accurate measurement of the temperature and/or pressure values, in other words the unstable behavior is easier to measure and detect.

[0050] Preferably, the method of the invention also includes the action of un-trapping said lubricant, said un-trapping including:

- ○ Switching off said compressor; or
- ○ Changing the speed of the motor of said compressor ; or
- ○ Changing a pressure drop of the refrigerant between an inlet and an outlet of said pressure-lowering device.

[0051] After the detection, Applicants have developed a method to remove the trapped lubricant from the branch (es) of the refrigerant circuit interested by the trapping and to bring it back into the compressor. Applicants have found that there are substantially three possible methods to achieve the removal of the oil, which can be used alternatively or in combination, as listed below.

[0052] In general terms, the un-trapping of lubricant from a pipe can be obtained changing the thermodynamic conditions in order to promote the miscibility of the refrigerant and the lubricant and/or increase the velocity of the refrigerant in the piping to detach the oil from the pipe's walls.

[0053] A first method of the invention to un-trap the oil includes operating a switch in order to switch off the compressor and keep it switched off for a given first pre-set interval of time. When the compressor is switched off, the temperature within the circuit decreases, promoting more favorable thermodynamic conditions for refrigerant-oil miscibility. The compressor is switched on again when the pre-set time interval has elapsed. At the moment in which the compressor is switched on again, this creates a "pressure wave" within the refrigerant circuit which favors the miscibility between the lubricant and the refrigerant, removing the trapping.

[0054] Alternatively, according to a different un-trapping method, the compressor's motor speed rate is increased. In variable speed compressor, it is possible to vary the motor speed. In case of oil trapping, therefore, the speed of the compressor is increased in order to increase the refrigerant flow rate and thus the refrigerant speed within the piping. With a high speed, the refrigerant is able to drug the oil back to the compressor. This higher than normal speed rate is kept either until the oil trapping status is not detected any more, for example continuously monitoring the pressure and/or temperature curve and not seeing any unstable trend, or for a given second pre-set interval of time. When no oil trapping is seen, then the previous parameters of the compressor before the detection of the oil trapping are restored or the compressor is controlled again on the basis of the logic of the cycle.

[0055] According to a third un-trapping method, the pressure-lowering device is operated in order to obtain a reduced pressure drop of the refrigerant. The pressure-lowering device of the refrigerant circuit includes for example an electronic valve the aperture of which can be regulated electronically or it may include a plurality of alternatively selectable capillaries in parallel. Therefore, when a lower pressure drop is desired, either a different capillary of the plurality is used, which leads to a lower pressure drop, or the electronic valve is actuated in order to change its aperture. Decreasing the pressure drop allows a higher refrigerant flow rate and higher refrigerant speed, for the following reasons. The flow rate of the refrigerant is determined by the sucking characteristics of the compressor, i.e. temperature and pressure, which means in particular that it depends on the pressure in the low pressure portion of the refrigerant circuit. If the pressure in the low pressure portion of the refrigerant circuit is increased, which is achieved lowering the pressure drop, the flow rate of the refrigerant increases due to an increase in its density. This implies a higher velocity of the refrigerant, not in the low pressure portion of the refrigerant, but in the high pressure portion, where more probably the oil trapping takes place. As previously stated, high speed of the refrigerant allows the refrigerant to drug the oil back to the compressor. The lower pressure drop is kept until the oil trapping status is detected, or for a pre-set time interval, then the previous conditions of the pressure-lowering device are set again.

[0056] As mentioned, preferably the apparatus of the invention includes a refrigerator or an air conditioner, where the second heat exchanger of the heat pump warms up the refrigerant and at the same time is apt to cool down a process medium used for refrigerating or air conditioning, respectively. Indeed in this case the process medium is air which is used either to refrigerate the refrigerator casing interior or a room. Alternatively, preferably the apparatus of the invention includes a laundry dryer, a washing machine, a washer-dryer or a dish-washer, all including a treatment chamber. In this case the first heat exchanger cools down the refrigerant and is apt to warm up a process medium apt to flow in the treatment chamber for drying or washing. The process medium in this case is either air or water.

[0057] The apparatus of the invention however is not only limited to appliances, but for example it can also be used in any other systems where an heat pump is used having a compressor and a refrigerant circuit in which oil trapping is probable.

Brief description of the drawings

[0058] These and other features and advantages of the invention will better appear from the following de-

scription of some exemplary and non-limitative embodiments, to be read with reference to the attached drawings, wherein:

- Fig. 1 is a perspective view, with a portion of the casing removed, of a laundry dryer realized according to the invention;
- Fig. 2 is a perspective view of a portion of the inside of the laundry dryer of fig. 1 in a disassembled condition;
- Fig. 3 is a schematic representation of the process air circuit and of the refrigerant circuit of the dryer of figs. 1 and 2;
- Fig. 4 is a schematic representation of a different embodiment of the process air circuit and of the refrigerant circuit of the dryer of figs. 1 and 2;
- Fig. 5 is the schematic representation of fig. 3 where some oil-trapping prone portions of the refrigerant circuit are highlighted;
- Figs. 6a and 6b are a schematic front and lateral view, in section, respectively, of the dryer of figs. 1 or 2;
- Figs. 7a and 7b are a schematic front and lateral view, in section, respectively, of the dryer of figs. 1 or 2 and 4;
- Fig. 8 is a schematic representation of figs. 3 or 4 where a possible action after oil trapping detection is depicted;
- Fig. 9 is a schematic representation of figs. 3 or 4 where a different action than the one in fig. 9 after oil trapping detection is depicted;
- Figs. 10a and 10b are graphs showing a different action than the ones in figs. 8 or 9 after oil trapping detection;
- Fig. 11 is a graph depicting the behavior of the refrigerant temperature versus time in different portions of the refrigerant circuit;
- Fig. 12 is a graph depicting the behavior of the refrigerant pressure versus time in different portions of the refrigerant circuit;
- Fig. 13 is a flow chart of the method to operate the laundry dryer of the invention;
- Fig. 14 is a flow chart of an embodiment of a phase of the method of fig. 14;
- Fig. 15 is a flow chart of a different embodiment of the phase of the method of fig. 15;
- Figs. 16a and 16b are two schematic lateral views of a detail of the refrigerant circuit of the dryer of fig. 1 according to two different embodiments of the invention.

Detailed description of the preferred embodiments

[0059] With initial reference to figs. 1 and 2, an apparatus realized according to the present invention is globally indicated with 1.

[0060] As a possible apparatus, a laundry dryer is described herein below, however the invention can be generalized to any apparatus including an heat pump.

[0061] Laundry dryer 1 comprises an outer box casing 2, preferably but not necessarily parallelepiped-shaped, and a drying chamber, such as a drum 3, for example having the shape of a hollow cylinder, for housing the laundry and in general the clothes and garments to be dried. The drum 3 is preferably rotatably fixed to the casing, so that it can rotates around a preferably horizontal axis (in alternative embodiments, rotation axis may be vertical or tilted). Access to the drum 3 is achieved for example via a door 3a, preferably hinged to casing, which can open and close an opening realized on the casing itself. Opening preferably faces drum 3 and it can be sealed by door 3a.

[0062] More in detail, casing 2 generally includes a front panel 20, a rear wall panel 21 and two sidewall panel all mounted on a basement 24. Panels 20, 21 and basement 24 can be of any suitable material. Preferably, the basement 24 is realized in plastic material. Preferably, basement 24 is molded.

[0063] Preferably, basement 24 includes an upper and a lower shell 24a,24b (visible in figure 2).

[0064] The dryer 1 defines an horizontal plane (X,Y) which is substantially the plane of the ground on which the dryer is situated, and a vertical direction Z perpendicular to the plane (X,Y).

[0065] Laundry dryer 1 also comprises an electrical motor assembly for rotating, on command, revolving drum 3 along its axis inside casing. Casing 2, revolving drum 3, door and motor are common parts in the technical field and are considered to be known; therefore they will not be described in details.

[0066] With now reference to figs. 3-5, dryer 1 additionally includes a process air circuit 4 which comprises the drum 3 and an air process conduit 11, schematically depicted in figs. 3, 4 and 5 as a plurality of arrows showing the path flow of a process air stream through the dryer 1. In the basement 24, air process conduit 11 is formed by the connection of the two upper and lower shells 24a, 24b. Air process conduit 11 is preferably connected with its opposite ends to two opposite sides of drum 3. Process air circuit 4 may also include a fan or blower 12 and an electrical heater (not shown in the figures).

[0067] The dryer 1 of the invention additionally comprises a heat pump 30 including a first heat exchanger called also condenser 31 and a second heat exchanger called also evaporator 32. Heat pump 30 also includes a refrigerant closed circuit 38 (schematically depicted in the picture with lines connecting the first to the second heat exchanger and vice versa, see in detail figs. 3-5) in which a refrigerant fluid flows, when the dryer 1 is in operation, cools off and may condense in correspondence of the condenser 31, releasing heat, and evaporates, potentially even warms up, in correspondence of the second heat exchanger (evaporator) 32, absorbing heat. Alternatively, no phase transition takes place in the condenser and/or evaporator, which indicates in this case respectively a gas heater and gas cooler, the refrigerant cools off or it warms up, respectively, without condensation or evaporation.

[0068] More in detail, the refrigerant circuit 38 connects via piping 35 the evaporator 32 via a compressor 33 to the condenser 31. The cooled or condensed refrigerant arrives via a pressure lowering device, such as an expansion device 34, for example a choke, or a valve or a capillary tube, back at the evaporator 32.

[0069] The compressor 33, preferably a single-stage or multi-stage sealed compressor, preferably including a variable speed motor, includes an inlet 33a, called also suction inlet for the suction of the refrigerant, and an outlet 33b for the exhaustion of the refrigerant. Within the compressor, a lubricant reservoir (not shown) is present, in order to provide lubricant for the lubrication of the moving parts of the compressor itself. Such a lubricant may leak within the refrigerant circuit 38, i.e. it can be present within piping 35. The inlet 33a is located at a "suction inlet level" L (see figs. 6a and 6b where the inlet pipe level is schematically shown with a dash-dotted line and in more details figs. 16a and 16b), so that the components of the refrigerant circuit which are located below the suction inlet plane are defined as being located below the "suction inlet vertical level".

[0070] With reference now to figures 16a and 16b, two embodiments of the compressor 33 are shown in detail. Compressor 33 includes a container 33e in which a top and a bottom 33c and 33d, respectively, are defined and which encloses a compressor chamber and a lubricant chamber (both not shown in the appended drawings). The suction inlet 33a defines the suction inlet plane L depicted as a dash-dotted in the drawings and its positioning is independent from the location of the compressor's bottom 33d. As visible in fig. 16b, the compressor 33 may also include a liquid-vapor separator 37, to avoid entrance of liquid in the compressor chamber of the casing 33e. Compressor 33 and liquid-vapor separator 37 are connected via piping 33f. It is to be understood that the suction inlet 33a defining the suction inlet plane L is always the suction inlet 33a of the compressor 33, and not the inlet 37a of separator 37. In the depicted embodiment, a portion of the piping 33f connecting separator 37 and compressor 33 is located below the suction inlet level L. Moreover, also in the compressor of fig. 16a without separator 37, the inlet pipe 33g connecting the suction inlet 33a to the refrigerant circuit 38 is located below the suction inlet level L.

[0071] The condenser 31 and the evaporator 32 of the heat pump 30 are located in correspondence of the process air conduit 11.

[0072] The dryer 1 of the invention can be a condense dryer - as depicted in the figures - where the air process circuit 4 is a closed loop circuit, the condenser 31 is located downstream of the evaporator 32. The air exiting the drum 3 enters the conduit 11 and reaches the evaporator 32 which cools down and dehumidifies the process air. The dry cool process air continues to flow through the conduit 11 till it enters the condenser 31, where it is warmed up by the heat pump 30 before re-entering the drum 3.

[0073] However the dryer of the invention can also be a vented dryer, not shown, in which the process air circuit 4 includes an exhaust duct connected to the drum 3 via an aperture into which the process air enters after having passed the whole drum 3 to de-humidify the laundry.

[0074] First and/or second heat exchanger 31, 32 further preferably include one or more heat exchanger modules 10 (shown only in fig. 2) located along the process air conduit 11, more preferably in correspondence of the basement 24 of dryer 1, as shown in fig 2 where the casing 2 and the drum 3 of the dryer 1 have been removed in order to show the heat exchangers located along the process air conduit 11.

[0075] According to the embodiment shown in figs. 4, 7a and 7b, the refrigerant circuit 38 may also include an auxiliary condenser 36 to improve the drying performances (efficiency and/or drying time) for example located downstream the condenser 31 and/or, as already described and shown in figs. 16a,16b and fig. 2, the liquid-vapor separator 37 upstream the compressor 33. The auxiliary condenser is used to further lower the temperature of the refrigerant.

[0076] According to a characteristic of the invention, the dryer 1, in correspondence of the refrigerant circuit 38, also includes a temperature sensor and/or a pressure sensor, both indicated with the reference number 39, in order to sense the temperature and/or the pressure level of the refrigerant flowing within piping 35. It is to be understood that although in the appended drawings only a single sensor in a single location is depicted, a plurality of sensors in different locations, as better explained below, can be present in the dryer 1 of the invention.

[0077] Preferably, the sensor 39 is apt to measure the temperature and/or pressure of the refrigerant in one or more of the branches of the piping which are called in the drawings 35a, 35b, and 35c (see respectively figs. 4, 7a and 7b) and output a signal which is function of the measured value.

[0078] Portion 35a corresponds to a portion of the piping 35 of the refrigerant circuit 38 upstream the suction inlet 33a of compressor 33, in particular between the inlet

33a of the compressor 33 and the outlet 32b of the evaporator 32. Portion 35b corresponds to a portion of the piping 35 of the refrigerant circuit 38 located between the outlet 31b of the condenser 31 and the expansion device 34. In case an auxiliary condenser 36 is present in the refrigerant circuit, the sensor is placed between the auxiliary condenser and the pressure lowering (or expansion) device. Alternatively, although not shown in the appended drawings, the sensor 39 can be located between the outlet of the pressure lowering device 34 and the inlet 32a of the evaporator 32. Portion 35c corresponds to a portion of the piping 35 of the refrigerant circuit 38 which is located below the suction inlet level L. This portion can be present due to the specific construction of the circuit 38 which is constrained by the limited space available in the basement 24, or to the presence of the additional condenser 36 (such as portion 35c, see figs. 7a and 7b). In fig. 7a and 7b, the additional condenser 36 is below the plane L, however the same oil trapping effect is obtained in portions at about the L level or slightly above , due to the fact that the gravity effect is not strong enough by itself to push the oil into the compressor.

[0079] The detection of the temperature and/or the pressure of the refrigerant is made for the whole duration of the drying cycle or for a portion of the same.

[0080] The sensor 39 is electrically connected to a processing unit 40 (see figs. 8 and 9) which elaborates the input signals received by sensor 39, as better explained below. In addition, processing unit 40 is apt to operate, for example via an electrical connection but a wireless connection can be envisaged as well, pressure-lowering device 34 and/or compressor 33, in order to send command signal to the same in response to the processed input signals from sensor 39.

[0081] In case of multiple sensors 39, all of them send the temperature and/or pressure detected signals as inputs to the processing unit 40.

[0082] The functioning of the dryer of the invention is as follows.

[0083] With reference to fig. 13, the dryer 1 is switched on (phase 1A) and a drying cycle among the list of available drying cycles is selected by a user (phase 2A). The drying cycle is thus started (phase 3A). After an initial transient phase (phase 4A) where the dryer 1 warms up and reaches the working temperature, a monitoring phase 5A to detect whether oil trapping is present in the refrigerant circuit is performed. It is to be understood that the oil trapping monitoring and determination according to the invention is made also optionally during the transient phase. In this phase 5A, sensor 39 preferably monitors the temperature and/or pressure (T and/or P) level of the refrigerant at a pre-defined frequency rate. For example, sensor 39 detects such a T and/or P value each second. Signals corresponding to these values are sent to the processing unit 40 where they are preferably stored and processed, and from the processing the presence or absence of oil trapping is obtained. It is then verified whether in the monitoring phase 5A oil trapping has been detected (phase 6A) or not. In case oil trapping is present, then preferably an oil un-trapping procedure (phase 7A) is initiated, at the end of which the program starts again from phase 4A. Otherwise, the monitoring phase continues (back to phase 5A).

[0084] In the monitoring phase 5A, as said, the temperatures and/or pressure values of the refrigerant are sensed and monitored by sensor 39. In figs. 11 and 12, a possible outcome of the monitoring of the temperature (fig. 11) and of the pressure (fig. 12) values of the refrigerant during the drying cycle is depicted. With reference to fig. 11, the upper most curve shows the behavior of the temperature values of the refrigerant in the proximity of the compressor outlet 33b during the drying cycle. The second curve from above shows the behavior of the temperature values of the refrigerant between the condenser 31 outlet 31b and the expansion device 34, during the drying cycle. In the same fashion, the third curve from above and the lowest curve show the behavior of the temperature values of the refrigerant in the proximity of the compressor inlet 33a and evaporator inlet 32a, respectively, during the drying cycle. In fig. 12, the two curves represent the behavior of the pressure values versus time in the proximity of the compressor inlet 33a and outlet 33b, respectively, in other words in both high and low pressure portions of the circuit 38. Pressure measurements, and not temperature measurements, can be made also downstream the outlet 33b of the compressor 33. At the outlet 33b, refrigerant and lubricant are mixed and temperature measurements will not show instability, however the pressure "waves" due to the unstable behavior caused by oil trapping are easily detected.

[0085] As highlighted by the sketched oval line of fig. 11, there is a region in the second, third and fourth curve where the behavior of the temperature curve becomes unstable, showing a plurality of subsequent extremes one after the others for a rather long time interval. This behavior in particularly enhanced in the second and third curve. Therefore, as mentioned above, the sensor 39 is preferably positioned in those portions of the refrigerant circuit where this unstable behavior is more easily detected.

[0086] The same behavior can be seen in the pressure curves as depicted in fig. 12.

[0087] The unstable behavior above analyzed is a sign of oil trapping. Therefore, the method of the invention, in the monitoring phase, is capable of recognizing such an unstable behavior of the pressure and/or temperature curve so that the oil trapping is detected.

[0088] More in detail, with now reference to fig. 14, phase 5A to monitor the oil trapping can be detailed as follows, according to the invention. The phase 5A is performed by the processing unit 40. In this phase, oil trapping can be calculated measuring the time elapsed between two adjacent extremes of the temperature and/or pressure values. If two consecutive extremes are popping up in a very short time frame, i.e. they are closer in time than a predefined *MinTime* threshold, then an un-

stable behavior is likely to be occurring, which means that oil is trapped somewhere in the refrigerant circuit 38. More in detail, the monitoring phase 5A starts (step 1B) and two variables *time* and *count* are initialized (e. g. they are set equal to zero) in step 2B. *Time* and *count* are substantially two counters. Temperature (or pressure) data *Temp* of the refrigerant are acquired by sensor 39 (step 3B). In the same step, for each data acquisition of *Temp,* the variable *time* is incremented (*time=time + 1)*. It is then checked (step 4B) whether an extreme has been detected in the *Temp* variable acquired data. Such an extreme might be either a maximum or a minimum of the *Temp* values. In case of no extreme has been detected, step 3B and subsequent ones are repeated. In case an extreme is detected, then the variable *count* is incremented *count= count + 1* (phase 5B). It is then checked whether the variable *count* has reached the value of 2 (step 6B): in the affirmative case, which means that two adjacent extremes have been detected, then it is also checked whether the variable *time* is below a pre-set constant *MinTime* (step 8B). The meaning of this step is substantially to check whether the two extremes showed up in a short time range (=*MinTime*). Possible values of *Min Time* are in the range of less than 10 minutes, for example 5 minutes. In the negative case, i.e. *count* is different than 2, the variable *time* is again initialized (i.e. set equal to 0; step 7B) and the phase 5A restarts from step 3B . In case *time* < *MinTime,* it means that oil trapping is present (step 9B), otherwise there is no oil trapping (step 10B). After both steps 9B or 10B, the phase 5A is then ended (step 11B).

[0089] Alternatively, according to a different embodiment of the method of the invention, phase 5A can be implemented as shown in fig. 15 by processing unit 40. In this phase, oil trapping can be detected counting the number of extremes present in the temperature/pressure curve in a given interval of time *MaxTime.* If in a given time interval there are "too many extremes", i.e. above a certain fixed number *Max Count,* then an unstable behavior is likely to be occurring. The monitoring phase starts (step 1C) and two variables *time* and *count* are initialized (e. g. they are set equal to zero) in step 2C. *Time* and *count* are substantially two counters. Temperature (or pressure) data *Temp* of the refrigerant are acquired by sensor 39 (step 3C). In the same step, for each data acquisition of *Temp,* the variable *time* is incremented (*time=time + 1*). It is then checked (step 4C) whether an extreme has been detected in the *Temp* variable acquired data. Such an extreme might be either a maximum or a minimum of the *Temp* values. In case of no extreme has been detected, it is also checked whether the variable *time* is above a pre-set constant *MaxTime* (step 6C). In case an extreme is detected, then the variable *count* is incremented count= count + 1 (phase 5C) and then step 6C is performed. In case *time* > *Max Time* (step 6C), then it is checked whether *count* is above a pre-set constant *Max Count,* i.e. whether the number of extremes has been detected in the interval of time *Max Time* (step 7C) is above the threshold Max Count. If *time* < *Max Time,* step 3C and subsequent ones are repeated. If *count* > *Max count* (step 7C), it means that oil trapping is present (step 8C), otherwise no oil trapping is detected (step 9C). After both steps 8C or 9C, the phase 5A is then ended (step 10C).

[0090] Alternatively, with now reference to figures 10a and 10b, phase 5A can be performed with the aid of a high pass filter (not shown in the appended drawings) connected to the processing unit 40. As visible in fig. 10a, which is a detail of fig. 11, in particular it is an enlargement of the temperature curve versus time of the refrigerant in proximity of the compressor inlet 33a, the temperature curve comprises a substantially constant portion followed by the unstable portion with a plurality of minima and maxima. If this electric signal coming from the sensor 39 is processed by a high pass filter, only the high frequency content (that is the part of the signal spectrum modified by the presence of trapped oil) is kept and the constant part becomes substantially equal to zero (see fig. 10b which is the filtered signal of fig. 10a). Measuring then the filtered signal, for example using the processing unit 40, if it overcomes a predefined threshold, for example the threshold can be of about 2°C in case of filtering a temperature curve, than there is oil trapped somewhere in the refrigerant circuit.

[0091] In particular, the operation of the High Pass Filter on the temperature (or pressure) values is the following:

$$T_F(n) = a \cdot T_F(n-1) + a \cdot [T(n)-T(n-1)]$$

Where T(n): raw input signal;
$T_F(n)$: filtered signal; and
a: filter coefficient (0<a<1)

[0092] As clearly seen by the trend of the curve in fig. 10b, the unstable part is greatly enhanced using the above mentioned filter.

[0093] In case oil trapping is detected in the circuit, the method of the invention includes the un-trapping phase 7A. The processing unit 40, having detected the oil trapping, consequently operates one or more of the components of the refrigerating circuit as better explained below.

[0094] Compressor 33, according to a preferred embodiment, includes a variable speed compressor. Phase 7A might include sending a command signal from the processing unit 40 to the compressor's motor in order to change the speed of the latter, in particular increasing the same. An increased speed stimulates the detachment of lubricant droplets from the piping walls. Preferably, the increased speed is kept for a pre-set time interval T_{is}, and then the compressor's motor speed is brought back to the normal operating speed. Alternatively, the increased speed is kept till oil trapping is not detected any more in phase 5A of the method of the invention.

This preferred embodiment of phase 7A is depicted in fig. 9 where with dot-dashed lines the communication lines between the sensor 39 and the processing unit 40, as well as the communication lines (wired or wireless) between the processing unit 40 and the compressor 33 are represented.

[0095] Alternatively, processing unit 40 sends to compressor 33 a switch-off signal in order to stop the functioning of the compressor. In this case, again with reference to fig. 9, when the compressor is switched off, the temperature within the refrigerant circuit 38 decreases, promoting more favorable thermodynamic conditions for refrigerant-oil miscibility. The compressor is switched on again when the pre-set time interval T_{SO} has elapsed. This interval is for example of about 5 minutes.

[0096] With now reference to fig. 8, processing unit 40 can be in signal communication with pressure-lowering device 34: in case of oil trapping, from processing unit 40 a selection signal is send to pressure-lowering device 34 in order to select the pressure drop between the inlet and the outlet of the latter. The pressure-lowering device 34 of the refrigerant circuit includes for example an electronic valve the aperture of which can be regulated electronically, or it may include a plurality of alternatively selectable capillaries in parallel (valve and capillaries not shown in the drawings). Therefore, either a different capillary of the plurality is used, which leads to a lower pressure drop, or the electronic valve is actuated in order to change its aperture. Decreasing the pressure drop allows a higher refrigerant flow rate, and higher refrigerant speed increases the chance of removing the oil droplets from the piping 35 walls.

Claims

1. A method to operate an apparatus (1) including a heat pump (30) to warm up or to cool down a process medium, the apparatus (1) including

   • A heat pump (30) having a refrigerant circuit (38) in which a refrigerant can flow, said refrigerant circuit (38) including a first heat exchanger (31) where the refrigerant is cooled off, a second heat exchanger (32) where the refrigerant is heated up, a compressor (33) to pressurize and circulate the refrigerant through the refrigerant circuit, said compressor (33) including a lubricant, and a pressure-lowering device (34); said first and/or second heat exchanger being apt to perform heat exchange between said refrigerant flowing in said refrigerant circuit (38) and said process medium;

   Said method comprising:

   • Monitoring the temperature and/or pressure value of said refrigerant in a location (35a,35b, 35c) within said refrigerant circuit (38); and
   • Determining lubricant trapping within said refrigerant circuit (38) on the basis of said temperature and/or pressure values versus time.

2. The method according to claim 1, wherein monitoring said temperature and/or pressure value includes identifying the extremes of said temperature and/or pressure values versus time.

3. The method according to claim 1 or 2, wherein said un-trapping includes:

   o Switching off said compressor (33); or
   o Changing the speed of a motor of said compressor (33); or
   o Changing a pressure drop of the refrigerant between an inlet and an outlet of said pressure-lowering device (34).

4. The method of claim 3, wherein changing a pressure drop of the refrigerant includes reducing said pressure drop, in order to increase the pressure in a low pressure portion of the refrigerant circuit (38).

5. The method of claim 3 or 4, including bringing the operational parameters of said compressor (33) and/or said pressure-lowering device (34) back to the values held before said un-trapping phase.

6. The method according to any of claims 2 to 5, wherein said monitoring further includes:

   • Counting the number of extremes within a preset time interval (Max Time), and
   • In case said number is above a given threshold (Max count), determining lubricant trapping.

7. The method according to any of claims from 2 to 5, wherein said monitoring further includes:

   • detecting the time elapsed between two consecutive extremes;
   • In case said time elapsed is below a given threshold (Min time), determining lubricant trapping.

8. The method according to any of the preceding claim, wherein monitoring the temperature and/or pressure value of said refrigerant includes:

   • Detecting a plurality of values of said pressure and/or temperature of said refrigerant;
   • Filtering said values using a high pass filter;
   • In case the mean of the filtered values is above a given threshold, signaling that lubricant trapping is determined.

9. An apparatus (1) including:

• A heat pump (30) having a refrigerant circuit (38) in which a refrigerant can flow, said refrigerant circuit including a first heat exchanger (31) where the refrigerant is cooled off, a second heat exchanger (32) where the refrigerant is heated up, a compressor (33) to pressurize and circulate the refrigerant through the refrigerant circuit, said compressor (33) including a lubricant, and a pressure-lowering device (34); said first and/or second heat exchanger being apt to perform heat exchange between said refrigerant flowing in said refrigerant circuit (38) and said process medium;

• A temperature and/or a pressure sensor (39) located within said refrigerant circuit (38) to detect a value of the temperature and/or the pressure of the refrigerant;

• A processing unit (40) apt to receive a signal sent by said sensor (39) based on said measured value; said processing unit (40) being able to determine lubricant trapping on the basis of said measured value versus time.

10. The apparatus (1) of claim 9, wherein said sensor (39) is located in a portion of said refrigerant circuit (38) between an outlet (32b) of said second exchanger (32) and an inlet (33a) of said compressor (33), or between an outlet (31b) of said first heat exchanger (31) and said pressure-lowering device (34), or between said pressure-lowering device (34) and an inlet (32a) of said second heat exchanger (32).

11. The apparatus (1) of claim 9 or 10, wherein said sensor (39) is located in a portion (35c) of said refrigerant circuit (38) located at a lower level than or at the vertical level (L) of a suction inlet (33a) of said compressor (33).

12. The apparatus (1) according to any of claims 9-11, wherein said refrigerant circuit (38) includes a high pass filter apt to filter said measured temperature and/or pressure values.

13. The apparatus (1) according to any of claims 9-12, wherein said apparatus (1) includes a refrigerator or an air conditioner, and wherein the second heat exchanger (32) of said heat pump (30) is apt to cool down said process medium used for refrigerating or air conditioning, respectively.

14. The apparatus (1) according to any of claims 9-12, wherein said apparatus includes a laundry dryer, a washing machine, a washer-dryer or a dish-washer, all including a treating chamber and wherein the first heat exchanger (31) is apt to warm up said process medium apt to flow in said treating chamber (3) for drying or washing.

15. The apparatus (1) according to any of claims 9-14, wherein said processing unit (40) is apt to perform an un-trapping of said lubricant, and wherein said apparatus (1) includes:

o A Switch operated by said processing unit (40) which is apt to switch off said compressor (33); or
o A variable speed compressor (33) operated by said processing unit (40) which is apt to change the speed of a motor of said variable speed compressor (33); or
o A tunable pressure-lowering device (34) operated by said processing unit (40) which is apt to change a pressure drop of the refrigerant between an inlet and an outlet of said tunable pressure-lowering device (34).

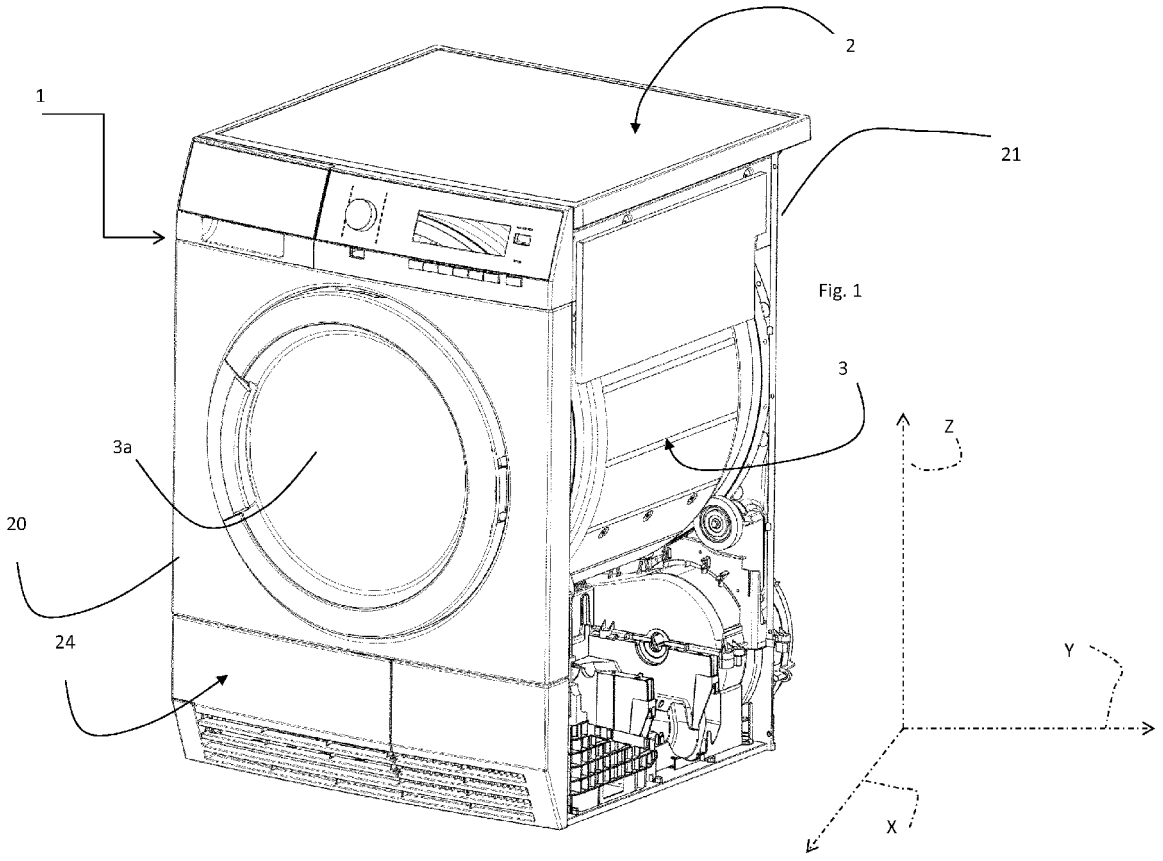


Fig. 1

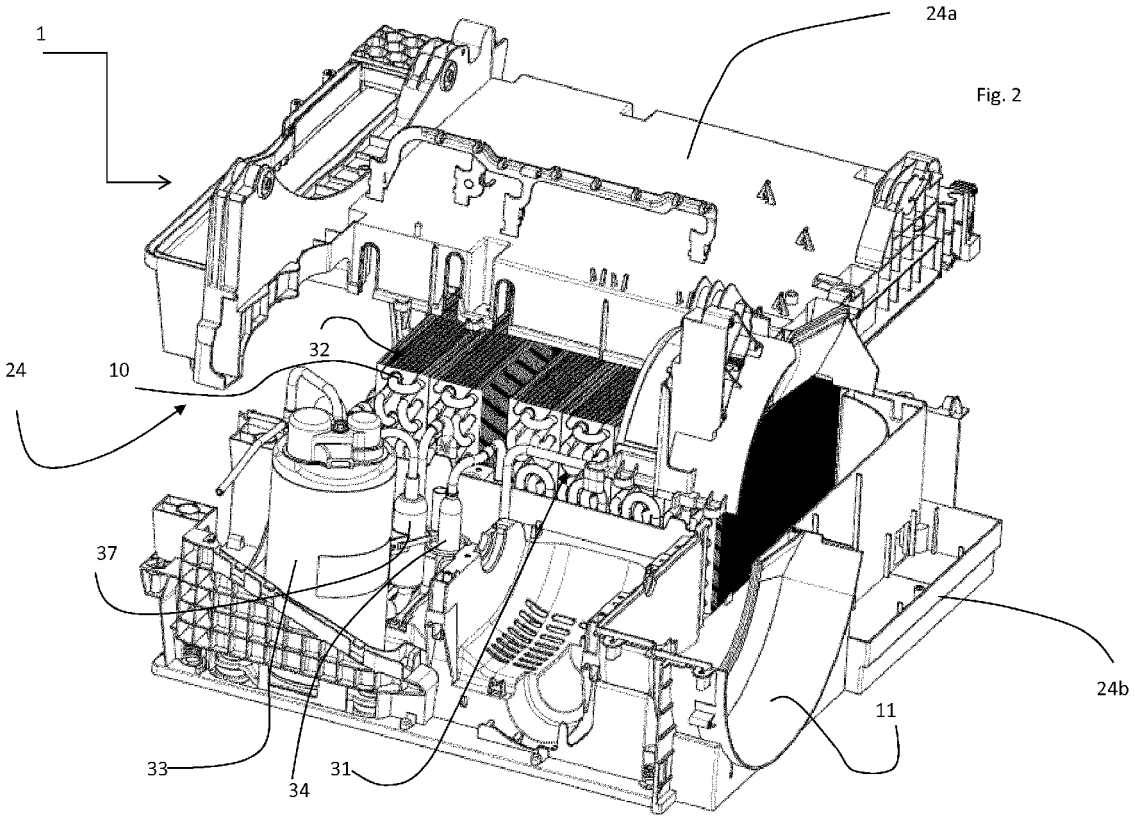


Fig. 2

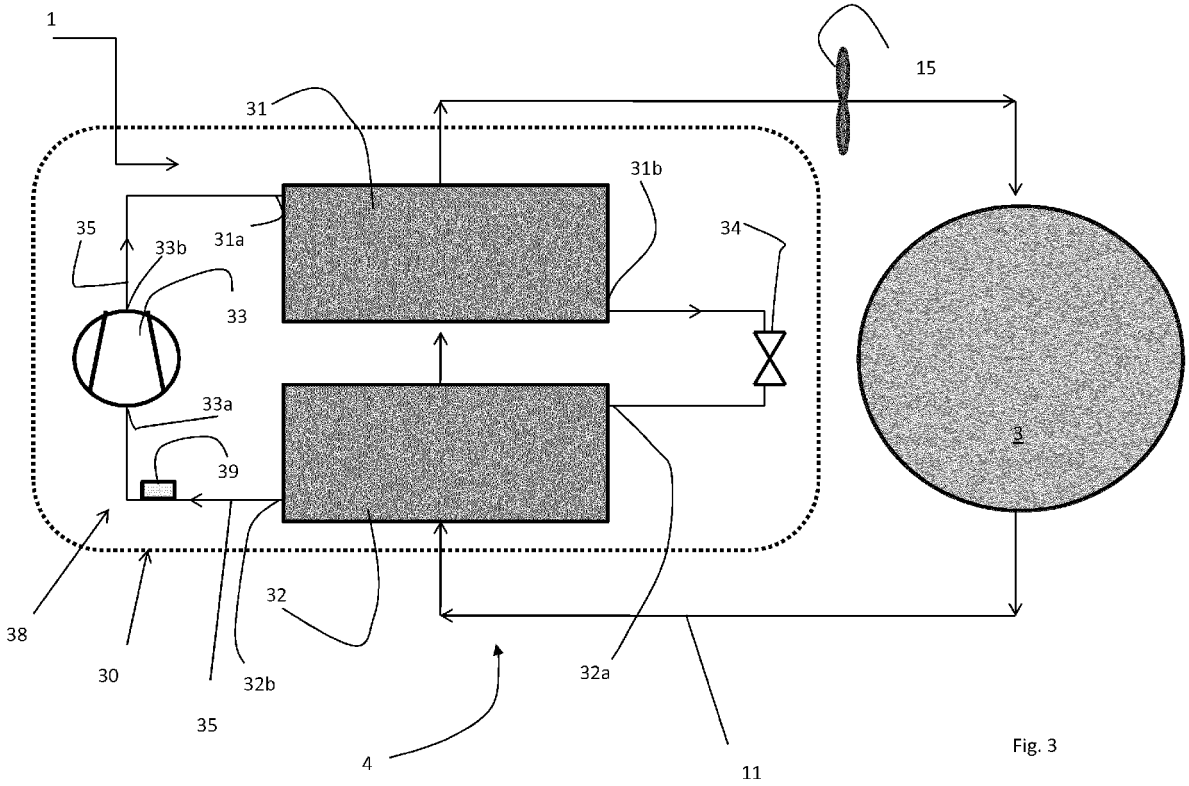


Fig. 3

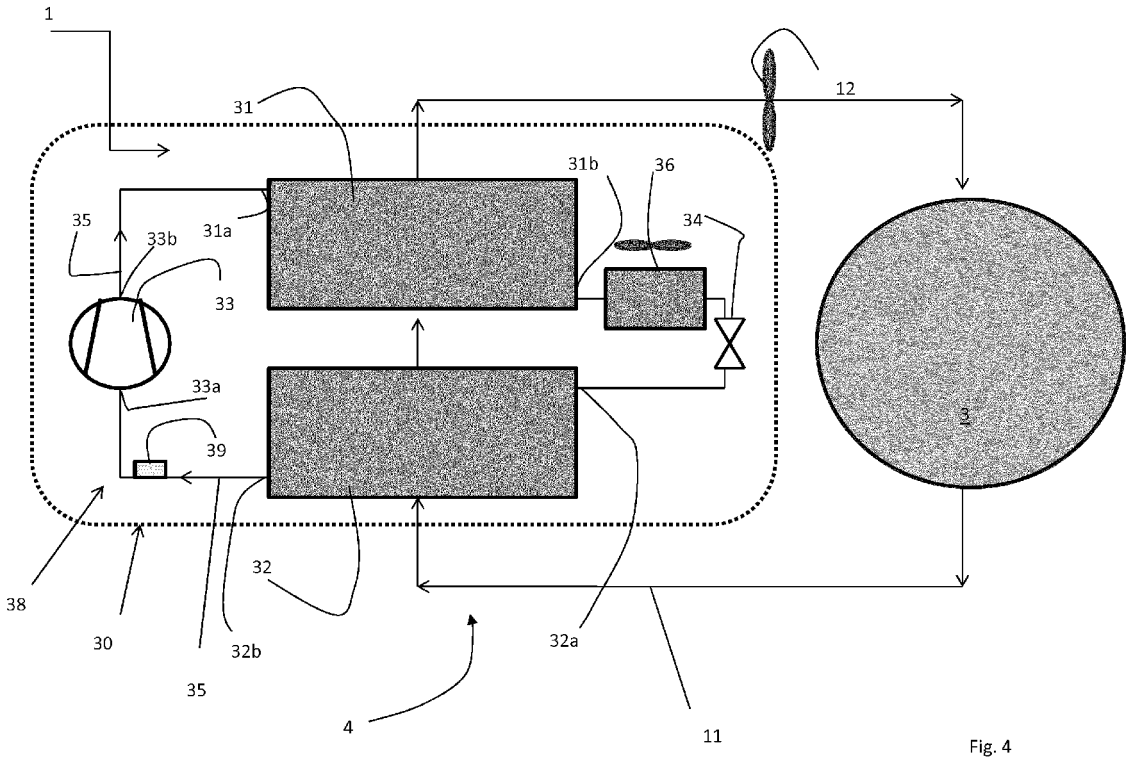


Fig. 4

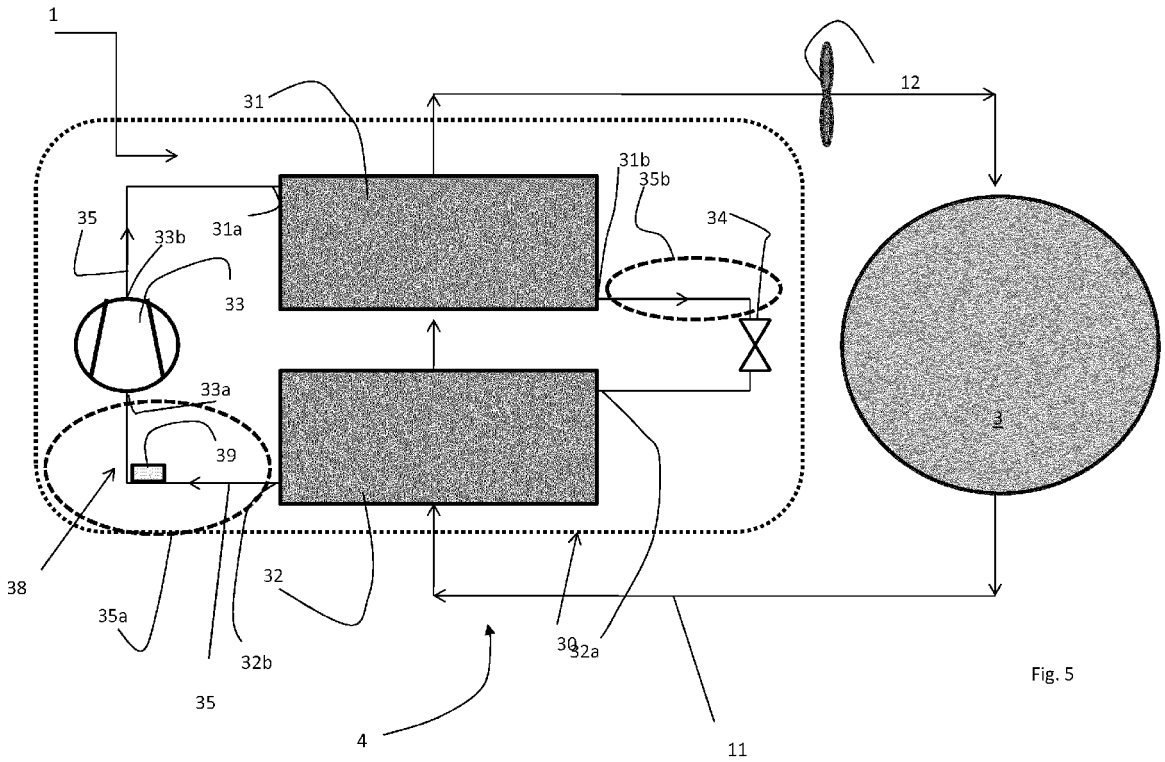
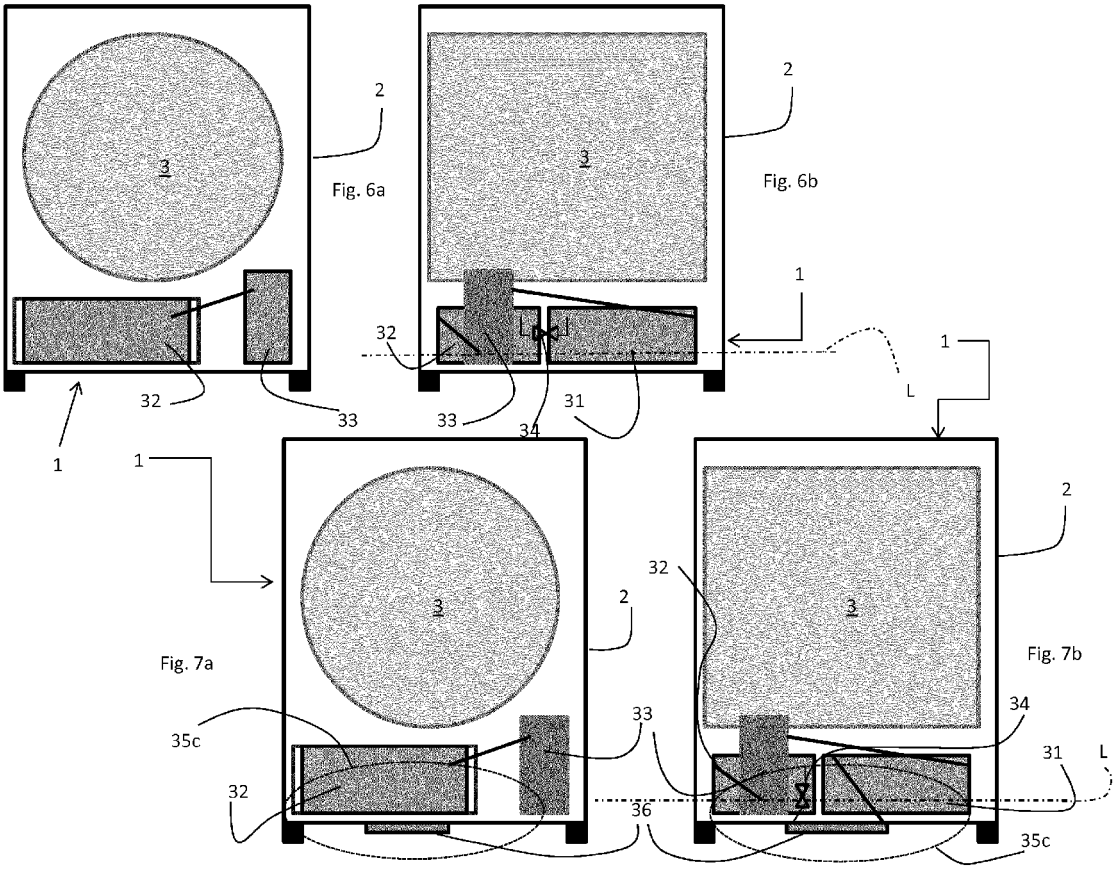


Fig. 5


3
2
Fig. 6a
3
2
Fig. 6b
1
32
33
1
1
L
1
32
33
34
31
3
2
Fig. 7a
35c
32
33
3
2
32
Fig. 7b
34
31
L
36
35c

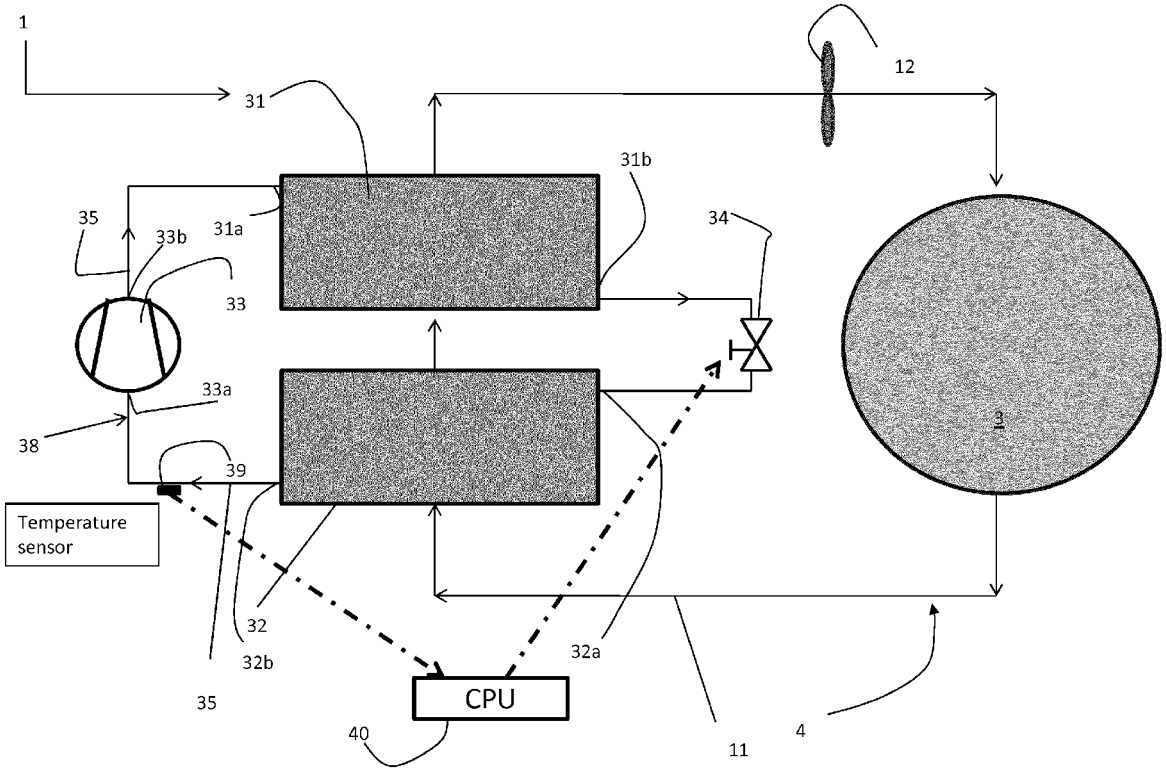

1
31
12
31b
35
31a
33b
34
33
33a
38
39
Temperature sensor
32
32b
35
CPU
40
32a
11
4

Fig. 8

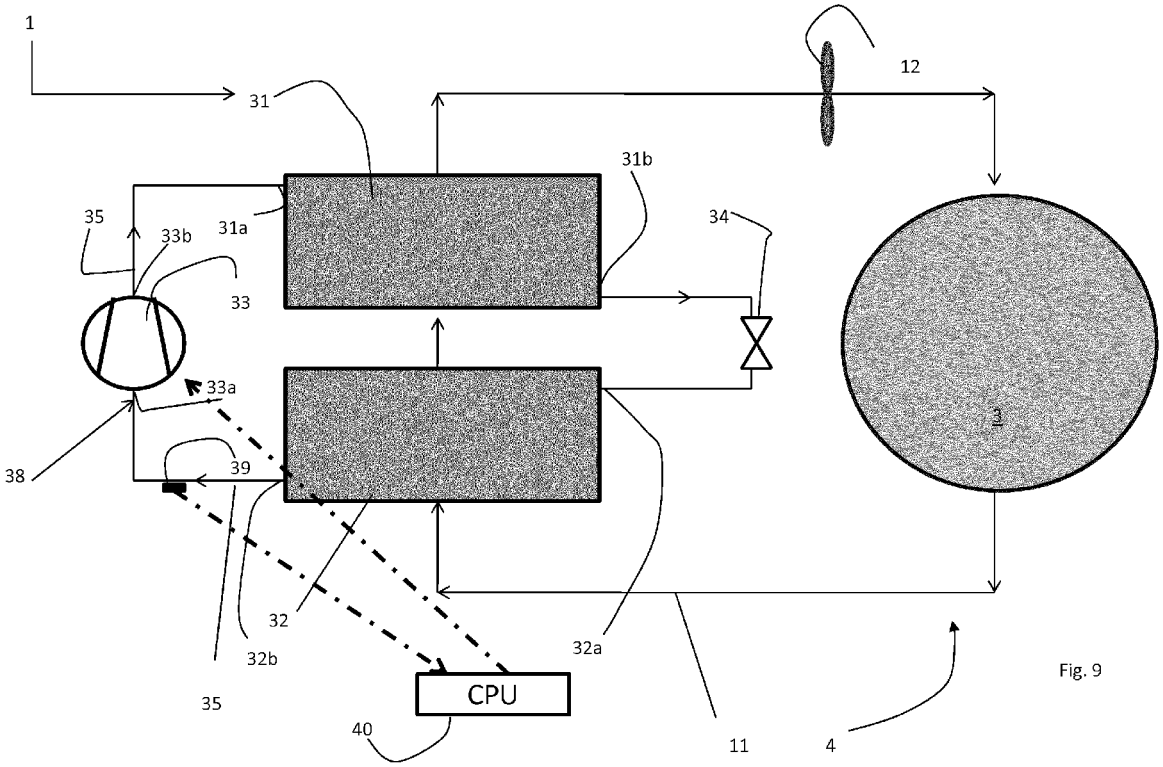


Fig. 9

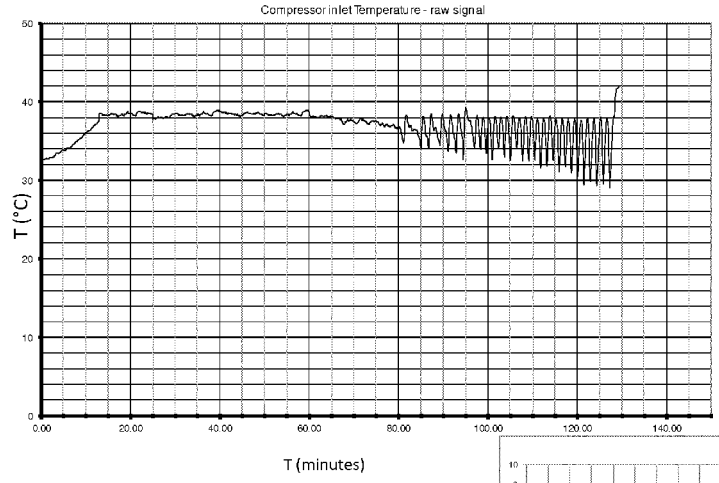


Fig. 10a

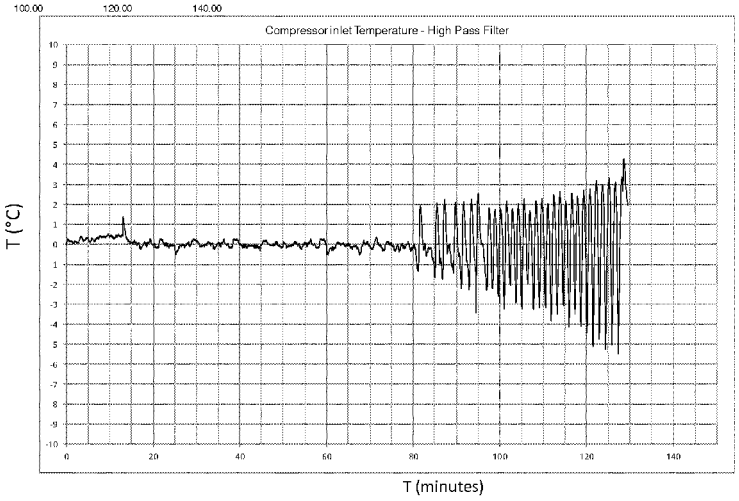


Fig. 10b

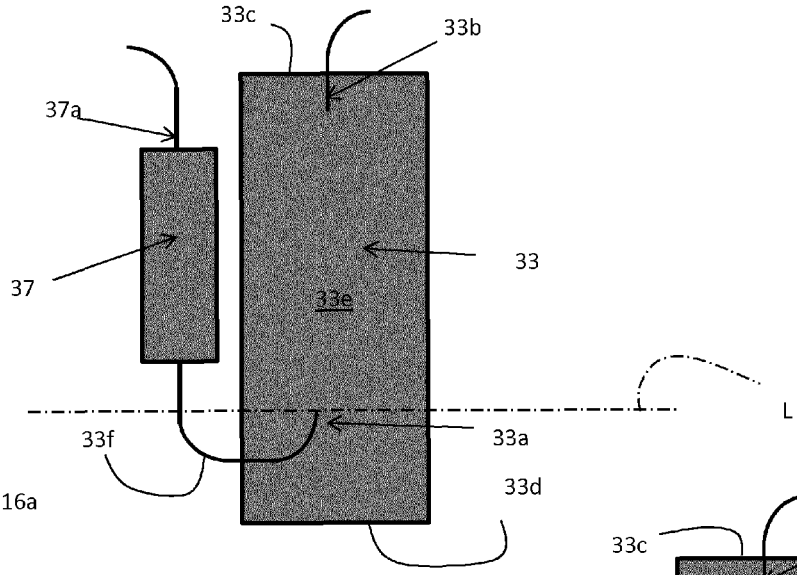


FIG. 16a

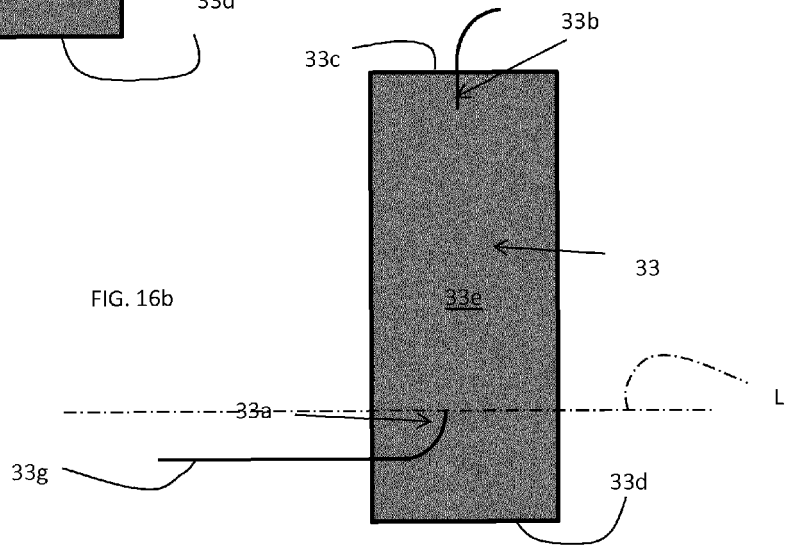


FIG. 16b

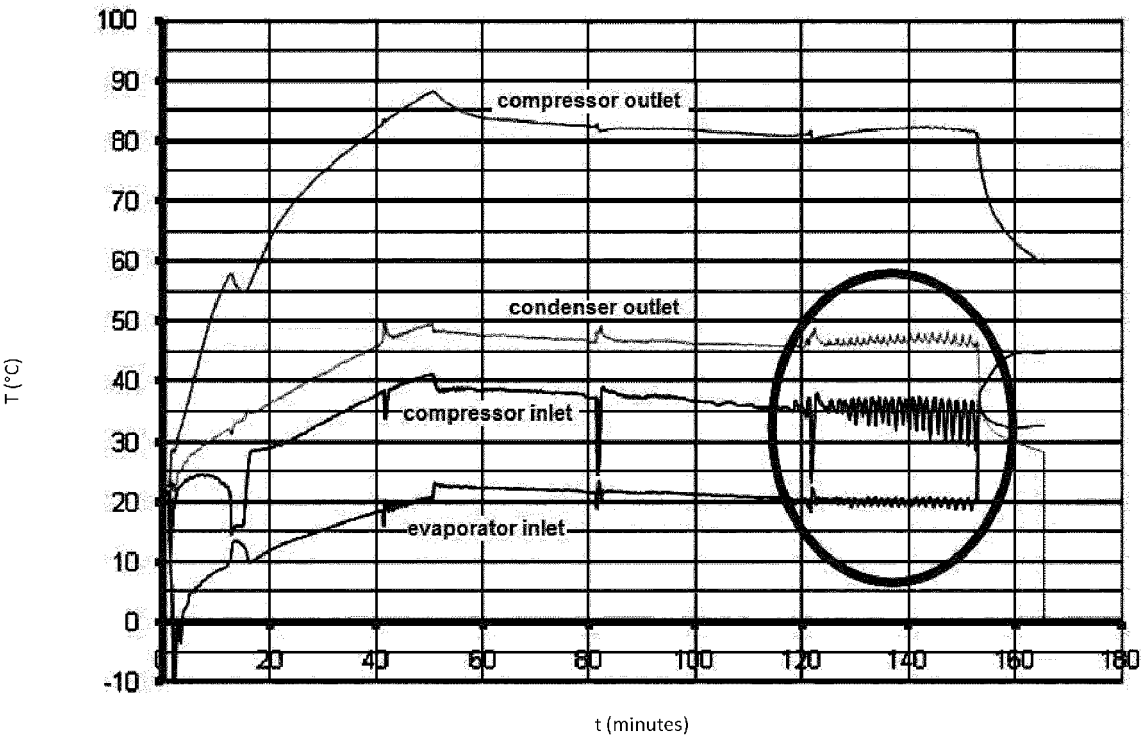

100
90
80
70
60
50
40
30
20
10
0
-10
0
20
40
60
80
100
120
140
160
180
compressor outlet
condenser outlet
compressor inlet
evaporator inlet
T (°C)
t (minutes)

Fig. 11

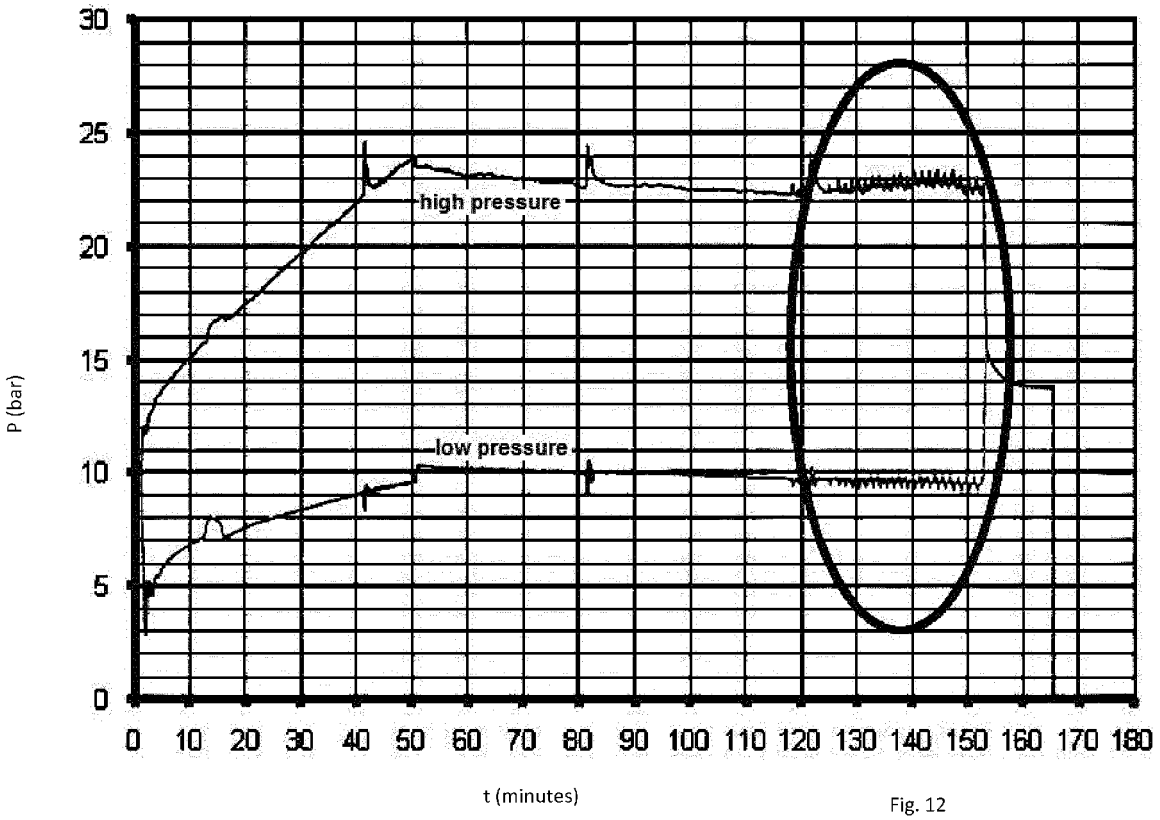

30
25
20
15
10
5
0
P (bar)
high pressure
low pressure
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
t (minutes)

Fig. 12

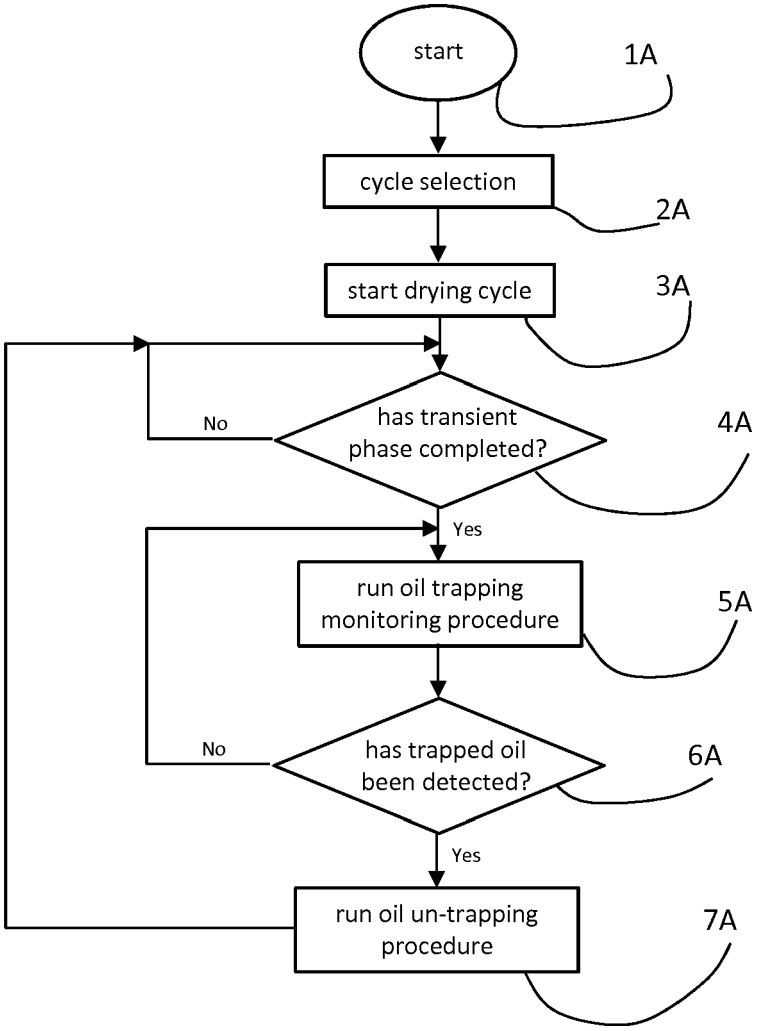

start
1A
cycle selection
2A
start drying cycle
3A
No
has transient phase completed?
4A
Yes
run oil trapping monitoring procedure
5A
No
has trapped oil been detected?
6A
Yes
run oil un-trapping procedure
7A

Fig. 13

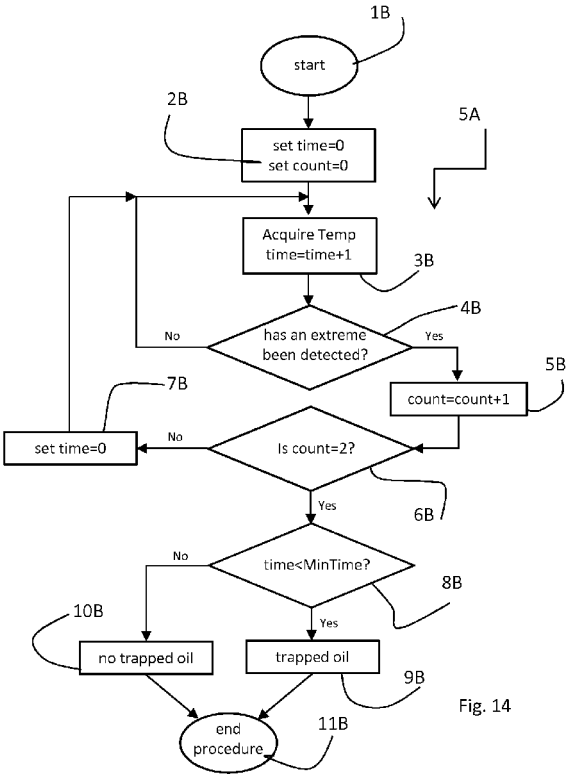

1B
start
2B
set time=0
set count=0
5A
Acquire Temp
time=time+1
3B
4B
has an extreme
been detected?
No
Yes
5B
count=count+1
7B
set time=0
No
Is count=2?
Yes
6B
No
time<MinTime?
8B
10B
Yes
no trapped oil
trapped oil
9B
end
procedure
11B

Fig. 14

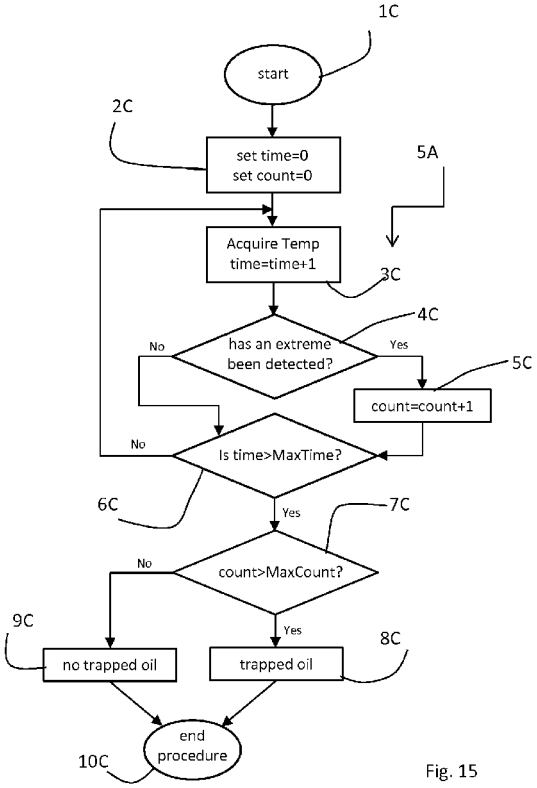

1C
start
2C
set time=0
set count=0
5A
Acquire Temp
time=time+1
3C
4C
has an extreme
been detected?
No
Yes
5C
count=count+1
No
Is time>MaxTime?
6C
Yes
7C
No
count>MaxCount?
9C
Yes
8C
no trapped oil
trapped oil
end
procedure
10C

Fig. 15

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EUROPEAN SEARCH REPORT

Application Number
EP 12 17 8075

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Place of search	Date of completion of the search	Examiner
Munich	12 December 2012	Gasper, Ralf

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