



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
01.02.2017 Bulletin 2017/05

(51) Int Cl.:
D06F 58/20 (2006.01) D06F 58/28 (2006.01)

(21) Application number: **15178405.5**

(22) Date of filing: **27.07.2015**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA

- **CASTIGLIONE, Massimo**
33080 Porcia (PN) (IT)
- **ZANDONA, Stefano**
33080 Porcia (PN) (IT)
- **CAMATA, Francesco**
33080 Porcia (PN) (IT)

(71) Applicant: **Electrolux Appliances Aktiebolag**
105 45 Stockholm (SE)

(74) Representative: **Electrolux Group Patents**
AB Electrolux
Group Patents
105 45 Stockholm (SE)

(72) Inventors:
• **CAVARRETTA, Francesco**
33080 Porcia (PN) (IT)

(54) **METHOD OF OPERATION OF A HEAT PUMP DRYING AND/OR WASHING APPLIANCE AND HEAT PUMP DRYING AND/OR WASHING APPLIANCE**

(57) The present invention relates to method to operate a washing and/or drying appliance (1) including

- A treating chamber where items are introduced and treated with a process medium;

- a heat pump (30) system 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 an electric motor, 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:

- storing a plurality (j) of data couples, a first element of each data couple being function of a maximum current value i_{MAXj} for the compressor electric motor current, and the second element of the couple being a corresponding function of a compressor maximum temperature value T_{MAXj} associated to the maximum current value i_{MAXj} of the first element, said plurality of data couples delimiting a safety work space for said compressor;
- measuring substantially at the same time a temperature value T_M representative of the temperature of said compressor and a current value i_M representative of the current absorbed by said electric motor of said compressor

while said heat pump is in operation;

- comparing said measured temperature value T_M and said measured current value i_M with said plurality of data couples; and

- cutting power supply to said compressor if:

- there is a data couple (T_{MAXj^*} , i_{MAXj^*}) in said plurality for which $|T_{MAXj^*} - T_M| = \min_j (|T_M - T_{MAXj}|)$ and $i_M \geq i_{MAXj^*}$ or
- there is a data couple (T_{MAXj^*} , i_{MAXj^*}) in said plurality for which $|i_{MAXj^*} - i_M| = \min_j (|i_M - i_{MAXj}|)$ and $T_M \geq T_{MAXj^*}$.

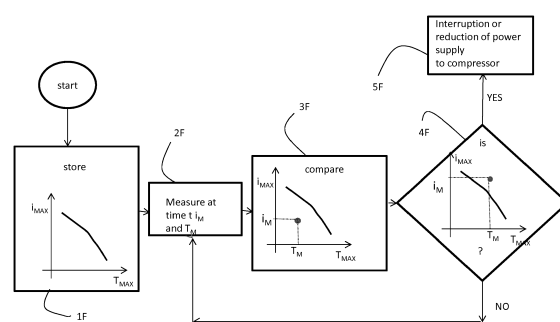


FIG. 6

Description

Technical field

[0001] The present invention relates to a method of operation of a drying and/or washing appliance including a heat pump. The method is directed to enhance safety and reduce drying time in a heat pump appliance compared to the appliances of the prior art. Further, the invention relates to a drying and/or washing appliance having a heat pump.

Technological background

[0002] Laundry dryers and washer/dryers including a heat pump system are becoming more and more widespread nowadays due to their efficiency and low energy consumption. In a heat pump system, besides the heat exchanger, also a compressor is present, which, as the name says, is apt to compress the refrigerant circulating within the heat pump system. The compressor, in order to perform its task, includes an electrical motor.

[0003] Many compressors employ numerous protection features to provide for safe and reliable operation of the compressor and the corresponding system, e.g. the heat pump system, in which the compressor is incorporated. As an example of compressor protection features, an internal overload protector may be included in the appliance to prevent the motor of the compressor from exceeding predetermined thermal limits during operation. The incorporation and inclusion of these protection features into a compressor can be very complex and costly to design and implement.

[0004] Further, generally overload protectors (OLP) include a bimetallic switch. When the OLP switches due to a too high temperature or current, a relatively long time is generally necessary before it cools down and thus can be switched back in the original position, allowing the restart of the heat pump. For this reason, the washing or drying cycles become very long and inconvenient for the user.

[0005] According to certain safety regulations and laws, before a washing and/or drying appliance can be introduced in the market, it has to pass several tests in order to prove its safety. One of those, for a heat pump appliance, includes operating the appliance under very harsh conditions and one of the test requirements is that the overload protector should not trip, that is, the current flow onto the motor of the compressor should not be interrupted. An accurate control of the temperature of the compressor and of the current absorbed in the motor of the same is thus required in order to avoid the tripping.

Summary of the invention

[0006] The present invention relates to a laundry appliance and a method of operation of a laundry appliance to dry and/or wash clothes or any other goods including

a heat pump. The control of the heat pump of the laundry appliance of the invention is improved compared to prior art laundry appliances and in particular a good control over the temperature of the compressor and/or the current absorbed by the motor of the compressor is achieved so that the laundry washing and/or drying appliance, and in particular the heat pump, can always work under safety conditions, without any risk, or only with minimal risk, of overheating.

[0007] The laundry appliance of the invention can be for example a laundry dryer, a washing machine or a laundry washer dryer.

[0008] It is known that a heat pump includes a refrigerant, a fluid which is evaporating and condensing. The heat pump compresses the refrigerant to make it hotter on the side to be warmed, and releases the pressure at the side where heat is absorbed.

[0009] The refrigerant, in its gaseous state, is pressurized and circulated through the system by a compressor. On the discharge side of the compressor, now hot and highly pressurized vapor is cooled in a heat exchanger, called a condenser, until it condenses into a high pressure liquid. The condensed refrigerant then passes through a pressure-lowering device which may be for example an expansion valve or a capillary tube. The low pressure liquid refrigerant then enters another heat exchanger, the evaporator, in which the fluid absorbs heat and evaporates. The refrigerant then returns to the compressor and the cycle is repeated.

[0010] The compressor can perform its function thanks to the energy derivable by an electric motor which absorbs a given current, for example from the mains.

[0011] Preferably, the compressor and its motor are housed in the same shell.

[0012] It is known in the art that a compressor of a heat pump, such as the heat pump present in laundry washing and/or drying appliances, can work under safety condition if it works in a field of temperature and current values which are both positioned below a curve having a shape and trend as depicted for example in fig. 5. Each compressor has its own specific curve delimiting its own safety working area which depends on the characteristics of the compressor itself. The temperature values in the graph of fig. 5 indicate the temperatures of the compressor itself while the current values indicate the current absorbed by the motor of the compressor.

[0013] As mentioned in the prior art, the requirement of working in such a safe field or working area is generally assured by the presence of a passive switch which interrupts the power supply to the heat pump compressor when predetermined thresholds of heat or current (or voltage load) are exceeded. The passive switch - or the OLP - opens when a threshold temperature of the heat pump compressor is reached or when a power load or current through the passive switch is reached, because also in this case a high current causes the bimetallic switch to overheat and reach the switching temperature.

[0014] When normal functioning conditions are re-es-

established, the passive switch (e.g. a thermo-protector such as the OLP) is adapted to go back to operative status closing the circuit; however there is a considerable delay before this happens. It is to be noted, in fact, that compressor OLP has a big inertia for turning back to the closed position, typically about 30 minutes.

[0015] In the prior art it has been proposed, in order to avoid this very long delay, to set a threshold temperature so that, when the temperature at the compressor exceeds this threshold temperature, the power to the compressor is interrupted. Applicant has realized that settings such as a temperature control where, when the temperature of the compressor raises above a limit temperature, the heat pump is stopped, is not an optimal solution. From the shape of the curve in fig. 5, it is clear that for some current ranges absorbed by the compressor's motor, the limit temperature could be too low and thus the heat pump is stopped in too many occasions, while for some other current ranges absorbed by the compressor, the set limit temperature could be too high and the OLP could trip anyhow.

[0016] Therefore a need for a different control is present, so that the heap pump can on one side always work in the safety field, without any actuation of the thermo-protector, and on the other hand the interruption of power to the compressor does not take place an excessive number of times.

[0017] The Applicant has realized that a control of both the current and the temperature is needed in order to solve the aforementioned problem.

[0018] According to a first aspect, the invention relates to a method to operate a laundry washing and/or drying appliance including

- A treating chamber where laundry is introduced and treated with a process medium;
- a heat pump system 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 an electric motor, 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;

said method comprising:

- storing a plurality (j) of data couples, a first element of each data couple being function of a maximum current value i_{MAXj} for the compressor electric motor current, and the second element of the couple being a corresponding function of a compressor maximum temperature value T_{MAXj} associated to the maximum

current value i_{MAXj} of the first element, said plurality of data couples delimiting a predetermined safety work space for said compressor;

- measuring, substantially at the same time, a temperature value T_M representative of the temperature of said compressor and a current value i_M representative of the current absorbed by said electric motor of said compressor while said heat pump is in operation;
- comparing said measured temperature value T_M and said measured current value i_M with said plurality of data couples; and
- limiting power supply to said compressor if:

there is a data couple (T_{MAXj^*} , i_{MAXj^*}) in said plurality for which $|T_{MAXj^*} - T_M| = \min_j (|T_M - T_{MAXj}|)$ and $i_M \geq i_{MAXj^*}$ or

there is a data couple (T_{MAXj^*} , i_{MAXj^*}) in said plurality for which $|i_{MAXj^*} - i_M| = \min_j (|i_M - i_{MAXj}|)$ and $T_M \geq T_{MAXj^*}$.

[0019] According to a second aspect, the invention relates to a laundry washing and/or drying appliance including:

- A treating chamber where laundry is introduced and treated with a process medium;
- a heat pump system 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 an electric motor, 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 memory storing a plurality (j) of data couples, a first element of each data couple being function of a maximum current value i_{MAXj} for the compressor electric motor current, and the second element of the couple being a corresponding function of a compressor maximum temperature value T_{MAXj} associated to the maximum current value i_{MAXj} of the first element, said plurality of data couples delimiting a predetermined safety work space for said compressor;
- A temperature and a current sensor apt to measure substantially at the same time a value indicative of a temperature of said compressor and a value indicative of an absorbed current of said compressor electric motor, respectively;
- A processing unit apt to receive a signal sent by said

temperature sensor and a signal sent by current sensor based on said measured values; said processing unit being able to compare said signals based on said measured temperature value T_M and said absorbed current value i_M with said plurality of data; and to limit power supply to said compressor if

- There is a data couple (T_{MAXj^*} , i_{MAXj^*}) in said plurality for which $|T_{MAXj^*} - T_M| = \min_j(|T_M - T_{MAXj}|)$ and $i_M \geq i_{MAXj^*}$ or
- There is a data couple (T_{MAXj^*} , i_{MAXj^*}) in said plurality for which $|i_{MAXj^*} - i_M| = \min_j(|i_M - i_{MAXj}|)$ and $T_M \geq T_{MAXj^*}$.

[0020] The appliance of the invention may be preferably a laundry dryer, a laundry washer dryer or a washing machine.

[0021] A heat pump appliance includes a treating chamber, such as a drum, in which the load of laundry, e.g., clothes, or other items to be washed and/or dried are placed. The treating chamber is part of a process circuit, in particular for example a closed-loop air circuit in case of a condensed dryer or an open air circuit in case of a vented dryer, which in both cases includes an air duct for channelling a stream of air to dry the load. The process air circuit is connected with its two opposite ends to the treating chamber. For example, in the case of a dryer, hot dehumidified air is fed into the treating 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 an evaporator of a heat pump, where the moist warm process air is cooled and the humidity present therein condenses. The resulting cool dehumidified air is then either vented outside the appliance in the ambient where the latter is located or it continues in the closed-loop circuit. In this second case, the dehumidified air in the process air circuit is then heated up before entering again in the drying chamber by means of a 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. Different circuits are known in the art in case of a washing machine or a washer-dryer.

[0022] The heat pump of the laundry appliance 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 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, heating up the process air before the latter is introduced into the drying chamber. 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 the second heat exchanger, the evaporator, in which the fluid absorbs heat and evaporates due to the heat exchange with the warm process air exiting the drying chamber. The refrigerant then returns to the compressor and the cycle is repeated.

[0023] In order to compress the refrigerant, the compressor includes an electric motor which is commonly powered by a current, for example a current coming from the mains.

[0024] The compressor, in order to work in safety conditions, should not overheat, that is, there is a field of working conditions, function of the temperature of the compressor and of the absorbed current of the electric motor of the compressor, in which the compressor can work without overheating. The field of safe working conditions for the compressor is generally delimited by a compressor curve such the one depicted in fig. 5. In the following the curve which delimits the "real" safety field of the compressor as given by the compressor manufacturer (or as obtained by field tests) is called "compressor curve".

[0025] In many appliances in which an overload protector OLP is present, this curve may represent a tripping curve of the OLP, that is, the curve of fig. 5 represents the temperature vs. current curve above which the OLP interrupts the supply of current to the compressor. The tripping curve of the OLP is generally provided, in a current-Temperature graph, as a triplet of curves having an "average" central curve comprised between two curves representing a minimum curve and a maximum curve. The area comprised between the minimum and the maximum curves indicates combinations of current and temperatures values that may cause tripping of OLP, i.e. and area where the OLP tripping may be possible, but not ensured. The central curve is the "average" curve for OLP tripping. The area beyond the maximum curve indicates that for points in such an area the OLP certainly trips, while the area below the minimum curve indicates that for points in such an area the OLP does not trip. In the following, for conciseness reasons, the triplet of curves will be called simply the "OLP curve". The safety field curve of the compressor (compressor curve) and the tripping curve of the OLP may not coincide, however the OLP tripping curve is generally below or equal the compressor curve, so that the compressor having an OLP can always work under safety conditions. This curve, although as said could be represented as a "strip" of values comprised between a maximum and a minimum curve, marks the boundary above which the OLP trips and it is called in the following "OLP tripping strip".

[0026] According to the present invention, in order to be sure that the compressor always works in the above mentioned safety field, that is, in the range of temperatures and absorbed currents by the motor which is not causing overheat, a control of the temperature and of the current has been implemented in the laundry appliance.

[0027] First of all, a predetermined safety field area or space is selected, in terms of temperature of the compressor and current to the compressor motor, in which it is desired that the compressor works. The control of the invention assures that the compressor is substantially only working in this predetermined safety field.

[0028] According to a first step of the method of the invention or according to an element of the laundry appliance, a plurality of data couples which delimits the predetermined safety work field space is obtained and stored, for example in a memory inside the laundry appliance. Such plurality of data couples could be a plurality of discrete couples, such as in a look up table, or a continuous curve. Each couple of the plurality (either continuous or discrete) includes a first element which is a value function of the maximum acceptable temperature by the compressor and a second element which is a value function of the maximum acceptable current absorbed by the compressor electric motor for the value of the temperature defined in the first element. Each couple therefore sets a "boundary-point" of the predetermined safety work field space of the compressor, that is, for values of current and/or temperature above such a point, the compressor is not working in the chosen predetermined safety field. Each data couple could be considered for example as a point belonging to the curve of fig. 5. It is to be understood that the predetermined safety field space could be different from the safety field space of the compressor as certified by the manufacturer, as detailed below.

[0029] In case of a look up table, where j ($j=1, \dots, \text{last}$) couples are stored, the various couples could be for example stored as

$T_{\text{MAX}1}, i_{\text{MAX}1}$

$T_{\text{MAX}2}, i_{\text{MAX}2}$

...

$T_{\text{MAX}j}, i_{\text{MAX}j}$

....

$T_{\text{MAXlast}}, i_{\text{MAXlast}}$

[0030] Each data couple of the table depicted above has the following meaning:

$T_{\text{MAX}j}$ is the j -th value function of the maximum temperature which is considered to be safe for the compressor at an absorbed current equal to $i_{\text{MAX}j}$, or vice-versa the couple can be seen as the maximum absorbed current $i_{\text{MAX}j}$ which is considered to be safe for the compressor at a temperature of the compressor equal to $T_{\text{MAX}j}$. Given a temperature value, therefore, from the look up table, the maximum current which can be absorbed by the compressor at such a temperature value can be checked and, in the same way, given a current value, from the look up table, the maximum working temperature at which the compressor can work when its motor absorbs such a current can be checked as well.

[0031] Each couple thus includes a first element, in the depicted table the temperature of the compressor, and

an associated second element, the current absorbed by the electric motor of the compressor. The temperature and current values could also be swapped for each couple, so that the current is the first element and the temperature the second element.

[0032] Alternatively, a continuous curve, which can be considered as made of an infinite number of data couples, instead of a look up table (which is defined as a finite number of data couples) can be stored inside the laundry appliance. Such a curve, called in the following "stored curve", can have any shape as long as it is below or it coincides with the curve of fig. 5 taken for a specific compressor. In the following a continuous curve is considered as a plurality of data couples, where the plurality is equal to infinity, so that the wording "a plurality of data couples" indicates both the look up table and the continuous curve.

[0033] In this embodiment in which a curve is stored, this curve can be stored as

$i_{\text{MAX}}(T) = f(T)$ where i_{MAX} and T are forming infinite data couples representing the maximum current as a function of the compressor temperature, or

$T_{\text{MAX}}(i) = g(i)$ where T_{MAX} and i are forming infinite data couples representing the maximum temperature as a function of the current absorbed by the compressor's motor.

[0034] Alternatively, both the above curves can be stored, for example in a memory of the laundry appliance. In an embodiment, these curves or look up tables can be stored in a control unit of the appliance.

[0035] The curve is made of an infinite number of couples, i.e. j is infinite, where the first element is the temperature (or the current) and the second element the derived (from the equation) corresponding current (or temperature).

[0036] The data couples in the look-up table or the stored continuous curve are in each point always below or equal to the safety curve known for a given compressor, that is, the stored curve or the couples in the look-up table are always below the compressor curve. In addition, such a curve or look-up table couples can be also below or equal to the OLP tripping strip for which the OLP trips. In addition, the stored curve or look up table couples could be below both the compressor curve and the OLP tripping strip without intersecting them in any point. Also the trend of the curve or of the couples in the look-up table stored in the laundry appliance can be arbitrary, they can form for example a step curve.

[0037] Among others, three different embodiments regarding the curve or look - up table are therefore foreseen in the present invention.

a. As mentioned above, the data couples of the look-up table or the stored curve can include points lying on the compressor curve or be the compressor curve itself. In this case, the look-up table couples or the stored curve represent the real boundary of the safety field for the compressor (predetermined safety field = real safety field of the compressor). The data

to create the look-up table or the stored curve are obtained from the compressor specifications and they are generally provided with the compressor itself from the manufacturer.

b. Alternatively, the couples in the look up table or the stored curve can include points lying on the OLP tripping curve or be the OLP curve itself, OLP curve for which the OLP trips and which is defined for each given OLP. The couples in the look up table or the stored curve can be representative of the minimum and/or maximum curve enveloping the OLP tripping strip. The curve of the OLP is always below or equal the compressor curve defining the boundary of the safety field for the compressor. Therefore, in this embodiment, the couples in the look-up table or the stored curve, representing the OLP curve, are located below or at the safety field curve of the compressor (used in embodiment a.).

c. In a different embodiment, each of the couples in the look-up table or the stored curve are always lying below the compressor curve, or the minimum curve which envelops the OLP tripping strip, that is to say, all values of the couples or the whole stored curve are located in the "safety field" defined below the compressor curve or the OLP tripping strip, curves that are specific for a given compressor or OLP respectively. The couples in the look-up table or the continuous stored curve are shifted to lower values of temperature and/or current with respect to the compressor curve or the OLP tripping strip, so the couples of the look-up table or the stored curve are well within the safety field area for the compressor, or well within the OLP intervention. Therefore, in this embodiment, a further safety is implemented, so that the real boundary of the safety field of the compressor, or the OLP activation are substantially never reached.

[0038] The look-up table or stored continuous curve is specific for a given compressor. If a different compressor is used, preferably a different look-up table or curve is used as well.

[0039] In order to check that the compressor of the heat pump works during the laundry appliance cycles within the predefined safety field area, two measurements are performed according to the invention. A first measurement, for example by means of a temperature sensor, is performed so as to acquire a value which is indicative of the temperature of the compressor. The temperature value measured does not have to be the temperature of the compressor, but it can be the temperature of another element, as long as it is possible to derive from it the temperature of the compressor.

[0040] Further, a second measurement is performed of a value indicative of the current absorbed by the motor of the compressor. The absorbed current can be measured in different ways. However, also a different value can be measured, and not directly the absorbed current

of the motor, as long as the absorbed current can be derived from it. A voltage measurement could be performed as well.

[0041] The two measurements are performed substantially at the same time t .

[0042] The results of the measurements are two values representing - or function of - the temperature of the compressor at the time t , T_M , and of the current absorbed by the electric motor of the compressor at time t , i_M .

[0043] The measured values are then compared, for example by means of the control unit, to the stored data couples, either in form of look up tables or curves.

[0044] Two ways to compare the results can be used. In a first embodiment, in case look up tables are used, the measured temperature is compared with the first elements (in this first embodiment, just by way of example, it is considered that the temperature is the first element and the current the second element of each stored couple) of the j stored couples. A specific couple is found for which the measured T_M is closest in value to the stored T_{MAXj} , that is, a couple (T_{MAXj^*} , i_{MAXj^*}) is searched in the look up table for which $|T_{MAXj^*} - T_M| = \min_j (|T_M - T_{MAXj}|)$.

[0045] It is selected among all j couples the one which has the first element having the smallest distance $d_j = |T_M - T_{MAXj}|$ to the measured value T_M . For example, all d_j can be calculated for all couples with j from 1 to last and the couple having the minimum d_j - called d_{j^*} - is selected. Preferably, the minimum distance d_{j^*} between the measured temperature and the closest value found among the couples, that is T_{MAXj^*} , is equal to or below 0.5°C . The fact that there is not a precise match between the first element of the closest stored couples and the measured value is due to the discrete nature of the look-up table, however it is preferred that there are enough couples in the look-up table that the predetermined boundary field is sampled each 0.5°C at least. To the found first element T_{MAXj^*} , a given i_{MAXj^*} as a second element is associated in the same couple, that is the T_{MAXj^*} for which $|T_{MAXj^*} - T_M| = \min_j (|T_M - T_{MAXj}|)$ is the first element of a couple and the second element of the couple is a given i_{MAXj^*} . This second element i_{MAXj^*} is then compared to the measured value of the current, that is, the second element of the couple is compared to i_M . If the measured current is above the maximum allowed current for the given temperature, then the compressor at time t is working outside the safety field area. This happens if

$$i_M \geq i_{MAXj^*}.$$

[0046] If instead of a look up table, a curve is stored in the control unit of the appliance, there is a perfect match, that is, the value T_M is the value of the selected point in the stored curve. The maximum current (second element of the couple, the first element is $T_{MAXj^*} = T_M$) is first calculated using the measured temperature value T_M via

the function

$$i_{MAXj*} = f(T_M)$$

and then this i_{MAXj*} is compared with the measured i_M as above. Again, if the measured current is above the maximum allowed current for the given temperature, then the compressor at time t is working outside the predetermined safety field area. This happens if

$$i_M \geq i_{MAXj*}.$$

[0047] In a second embodiment, in case look up tables are used, the measured current is compared with the second elements (in this second embodiment it is also considered that the temperature is the first element and the current the second element of each stored couple) of the stored couples. A specific couple (T_{MAXj*} , i_{MAXj*}) is found for which the measured i_M is closest in value to the stored i_{MAXj*} , that is, a couple is searched in the lookup table for which $|i_{MAXj*} - i_M| = \min_j(|i_M - i_{MAXj}|)$.

[0048] It is selected among all j couples the one which has the first element having the smallest distance $d_j = |i_M - i_{MAXj}|$ to the measured value i_M . For example, all d_j can be calculated for all couples with j from 1 to last and the couple having the minimum d_j - called d_{j*} - is selected. It is selected among all j couples the one which has the first element having the smallest distance $d_j = |i_M - i_{MAXj}|$ to the measured value i_M . For example, all d_j can be calculated for all couples with j from 1 to last and the couple having the minimum d_j - called d_{j*} - is selected. Preferably, the minimum distance d_{j*} between the measured current and the closest value found among the couples, that is i_{MAXj*} , is equal to or below 0.1 A. The fact that there is not a precise match between the second element of the closest stored couples and the measured value is due to the discrete nature of the look-up table, however it is preferred that there are enough couples in the look-up table that the predetermined boundary field is sampled each 0.1 A at least. To the found i_{MAXj*} , a given T_{MAXj*} is associated, that is the i_{MAXj*} for which $|i_{MAXj*} - i_M| = \min_j(|i_M - i_{MAXj}|)$ is the second element of a couple and the first element of the couple is a given T_{MAXj*} . This first element T_{MAXj*} is then compared to the measured value of the temperature, that is, the second element is compared to T_M . If the measured current is above the maximum allowed temperature for the given current, then the compressor at time t is working outside the safety field area. This happens if

$$T_M \geq T_{MAXj*}.$$

[0049] If instead of a look up table a curve is stored in the control unit of the appliance, there is a perfect match, that is, the value i_M is the value of the selected point in the stored curve. The maximum temperature (first element of the couple, the first element is $i_{MAXj*} = i_M$) is first calculated via the function

$$T_{MAXj*} = g(i_M)$$

and then this T_{MAXj*} is compared with the measured T_M as above. If the measured current is above the maximum allowed temperature for the given current, then the compressor at time t is working outside the safety field area. This happens if

$$T_M \geq T_{MAXj*}.$$

[0050] If the value of the measured current and/or the measured temperature are outside the safety field area, then the compressor receives a limitation in the power supply, which may include a power reduction or a complete power cut.

[0051] The step of limiting the power supply to the compressor could include to supply the compressor with a reduced power or with no power at all, that is, for example the power to the motor of the compressor is cut off, because the compressor is not working in the prescribed temperature/current field. The decision whether the power is reduced or cut off completely depends, among others, on the choice of the predetermined safety field, which in turn imply the choice of the stored curve or of the couples of the look-up table. In case for example the predetermined safety field coincides - as in the embodiment a. - with the real boundary for a safe functioning of the compressor (the compressor curve), when such a safety field is exceeded, it is preferred to cut the power supply completely. Alternatively, in a case like embodiment c. where although the couples in the look-up table or the curve are exceeded by the measured values, the real safety field probably is not exceeded yet, thus the power to the compressor could be reduced, because there is a "buffer" of safety field area before reaching the real boundary of the safety field of the compressor.

[0052] Therefore, according to the invention, as soon as the boundary imposed by the stored curve or the look-up table of the predetermined safety field are exceeded, the power to the compressor is limited because there is the risk that the compressor may overheat or the OLP may trip.

[0053] Thus, in particular in embodiment b. and c., if the laundry appliance of the invention includes an OLP, the control of the invention prevents the OLP from tripping because it interrupts or limit the flow of current to the compressor electric motor even before the activation of

the OLP, being all the data couples or stored curve below the tripping curve of the OLP. In particular, all the data couples or stored curve are below the minimum curve which envelops the OLP tripping strip. In this way, the compressor can be cooled and restarted in a much quicker way than in cases in which the OLP interrupts the current flows. Further, in case the laundry appliance includes an OLP, the method and appliance of the invention act as a "double security", so that in case of a double failure of two components in a control circuit in the laundry appliance, the compressor still will not overheat, being shut down or having a more limited power either by the OLP or by the control of the invention.

[0054] On the other hand, also when the OLP is not present, the control of the invention forces the compressor to work always in the predetermined safety field of operation, because otherwise - outside such a field - the current to the compressor is cut off or reduced.

[0055] It is to be understood that the inclusion of an OLP is only one of the possible embodiments of the invention. The laundry appliance of the invention and/or operating according to the method of the invention could also be "OLP-free", that is the control of the invention allows removing the OLP from the laundry appliance and at the same time guaranteeing the same safety level. In that case, the data couples of the look-up table or the stored curve can include points lying on the compressor curve or be the compressor curve itself (embodiment a.).

[0056] The invention, according to the first or second aspect, may include in combination or alternatively any of the following characteristics.

[0057] Preferably, limiting power supply to the compressor includes:

- switching OFF said compressor electric motor; or
- adjusting a rotational speed of the compressor electric motor.

[0058] In order to limit the power supply to the compressor, a first possibility is to stop the electric motor of the compressor, switching it off. In this case a complete power cut is obtained. Alternatively, a second possibility is to change, such as to reduce, the rotational speed of the motor of the compressor. In this way the limitation of the power supply is obtained.

[0059] The choice whether to cut power completely or only to reduce it depends on the selected embodiment, that is, on the selected predetermined safety field.

[0060] Preferably, the method of the invention further comprises:

- Providing a compressor cooling fan in proximity of said compressor; and, if said power to said compressor has been cut, one or more of:
 - Switching ON said compressor cooling fan;
 - adjusting an upper threshold temperature of the refrigerant for driving the switching ON of

said compressor cooling fan;

- adjusting a lower threshold temperature of the refrigerant for driving the switching OFF of said compressor cooling fan;
- adjusting a rotational speed of said compressor cooling fan;
- adjusting an ON/OFF ratio of said compressor cooling fan.

[0061] As soon as it has been found out that the compressor was working outside the safety field area and thus the current has been cut off, one or more possible corrective actions can take place in order to modify the compressor status so that it can be moved as soon as possible back into the safe working field, so that the cycle is not interrupted for a very long time. Such corrective actions, in case a compressor fan is present to blow air onto the compressor, can be: immediately switch on the compressor cooling fan to decrease the time needed by compressor to cool. This action is useful when a current absorption peak is present, since when the power cut off is due to excessive heat it is likely that the fan is already on. Alternatively or in addition, the control unit may modify an upper threshold temperature of the refrigerant which drives the switching on of the compressor cooling fan and/or modify a lower threshold temperature of the refrigerant which drives the switching off of the compressor cooling fan to ensure better compressor cooling. For example, the upper threshold temperature of the refrigerant at which the fan is switched on can be decreased. Additionally or alternatively, the lower threshold temperature of the refrigerant at which the fan is switched off could be decreased. A further alternative could be to modify the rotational speed of the fan, e.g. above a predetermined refrigerant temperature, to improve the cooling of the compressor, particularly increasing the rotational speed of the fan. Alternatively, due to the fact that often the compressor cooling fan is not a variable speed fan for costs reasons, the ON/OFF ratio of the compressor cooling fan is changed, and preferably increased.

[0062] Preferably, the method, when said process medium is drying air flowing in a process drying air circuit and said apparatus is apt to dry items, comprises:

- Providing a process fan to move air within said process air drying circuit; and, if said power to said compressor has been cut, one or more of:
 - Switching ON, or keeping switched ON said process fan;
 - adjusting a rotational speed of said process fan.

[0063] Also modifications to the process fan motor parameters may be applied to try to ensure better cycle conditions. An option could be to modify, in particular to increase, the motor speed of the process fan to ensure higher air flow. Alternatively, another solution could be

to increase motor speed during motor rotation direction inversion phase to increase the available drying air flow during this phase.

[0064] Advantageously, the method further comprises:

- adjusting the rotational speed and/or the clockwise/counterclockwise rotation ratio of a motor adapted to drive into rotation the treating chamber.

[0065] Also modifications to the treating chamber, such as the drum, can be applied to try to ensure better cycle conditions: a first possibility is to modify drum motor reversing behavior, this is relevant when a single motor drives both the process fan and the treating chamber. During motor reversing phase, the rotation direction of the motor is changed to better tumble the laundry, however the process fan provides only a part of the nominal flow rate available when the process fan rotates in the main direction and the decrease of drying air flow can worsen compressor working condition. To try to improve this aspect, it is possible to reduce motor stop time and/or reduce the time interval of the motor rotation direction inversion phase; or to reduce reversing frequency includes the chance to completely avoid any reversing for the remaining duration of the cycle; or to increase motor speed during motor rotation direction inversion phase to increase the available drying air flow during this phase. Alternatively, the laundry could be stuck in a given position within the treating chamber and could block the flow of process air, overheating the compressor. Therefore, changing the rotation speed or the rotation direction of the treating chamber could re-position the laundry and allow the process air to flow again.

[0066] In a preferred embodiment, the method comprises:

- Setting a threshold safety value i_{safety} ;

And wherein comparing said measured temperature value T_M and said measured current value i_M with said plurality of data couples includes:

- Comparing said measured temperature value T_M with said plurality of data couples;
- Determining a data couple (T_{MAXj^*}, i_{MAXj^*}) for which $|T_{MAXj^*} - T_M| = \min_j(|T_M - T_{MAXj}|)$;
- comparing a maximum current value i_{MAXj} of said data couple corresponding to the determined closest maximum temperature value T_{MAXj} to the measured current value i_M ;
- limiting power supply to said compressor if $|i_{MAXj^*} - i_M| \leq i_{safety}$.

[0067] As mentioned, the curve or the lookup table stored in the appliance could delimit the safety working field area of the compressor, obtained for example from test studies on the compressor, from the manufacturer, etc. (embodiment a.), or could be similar to a character-

istic strip of the OLP which might be present in the appliance (embodiment b.), or could be positioned below both the OLP tripping strip and the compressor curve (embodiment c.) depending on the chosen predetermined safety field. In any case, in order to even further assure that the compressor is always working in the predetermined safety field, in this preferred embodiment a further constraint is set: the measured current absorbed by the motor of the compressor at a given measured temperature should be not only lower than the point in the curve or value in the lookup table at about the same temperature, but also lower than that value plus at least an extra "safety addition", which is called safety value i_{safety} .

[0068] Thus, given a measured value T_M , the couple having the closest value of the first element to this measured value is selected. This couple (T_{MAXj^*}, i_{MAXj^*}) is determined by calculating the T_{MAXj^*} among all T_{MAXj} $j=1 \dots \text{last}$ for which $|T_{MAXj^*} - T_M| = \min_j(|T_M - T_{MAXj}|)$. The second element of the couple i_{MAXj^*} is then compared to the measured value i_M and it is checked whether $|i_{MAXj^*} - i_M| \leq i_{safety}$.

[0069] If this is the case, that is, if the measured current at a given measured temperature is closer to the curve or the look-up table second element value at about the same temperature of less than the safety value i_{safety} , the power to the compressor is limited. In the embodiment c. where the stored curve or stored look-up table is already below the compressor safety field boundary curve, preferably the power to the compressor, because this safety value i_{safety} is an additional safety on top of the already existing safety shift of the stored curve or look-up table with respect to the real boundary of the compressor safety field. In the embodiments a. or b., preferably the power to the compressor is reduced if $i_M \leq i_{MAXj^*}$, otherwise the compressor is switched off.

[0070] Advantageously, the method comprises:

- Setting a threshold safety value T_{safety} ;

[0071] And wherein comparing said measured temperature value T_M and said measured current value i_M with said plurality of data couples includes:

- Comparing said measured current value i_M with said plurality of data couples;
- Determining a data couple (T_{MAXj^*}, i_{MAXj^*}) for which $|i_{MAXj^*} - i_M| = \min_j(|i_M - i_{MAXj}|)$;
- comparing a maximum temperature value T_{MAXj^*} of said data couple corresponding to the determined closest maximum current value i_{MAXj^*} to the measured temperature value T_M ;
- limiting power supply to said compressor if $|T_{MAXj^*} - T_M| \leq T_{safety}$.

[0072] This is a preferred embodiment analogous to the one described above, reversing the checking order of the measured values of current and temperature with the plurality of stored couples.

[0073] Preferably, the method includes:

- Switching ON again said compressor after a predetermined time is elapsed from a switching OFF of the compressor motor;
- Restore the compressor power supply as it was before the power limitation was made; or
- Supplying said compressor with a power which depends on a selected drying cycle when said measured temperature value T_M is below a predetermined threshold.

[0074] Any of the possible corrective actions above discussed, or others, may lead to a cooling down of the compressor in a rather quick time frame, in general quicker than the cooling down of an OLP. The compressor can be thus switched on again after a predetermined time has elapsed, or the power supply can come back to "normal", if the temperature of the compressor (which could be the temperature of the refrigerant) has become stabilized below a given threshold. The "normal" power supply depends generally on the drying cycle, or, in general, the laundry treatment cycle, selected by a user and it is stored, for example, in a control unit of the laundry dryer. In this way, if the compressor has been switched off, it can be switched on again relatively rapidly. For example, an additional feedback on the temperature can be present, that is, the compressor can be switched on again after the predetermined time has elapsed only if also the compressor temperature is below a given threshold. If the power has been only reduced, then such power can also go back to the value it had before the power limitation was made, depending on the temperature of the compressor. Also in this case for example an additional feedback loop can be present, so that in addition of being below a threshold, a given time has to elapse before the compressor can be supplied at a predetermined power.

[0075] Advantageously, the method comprises:

- Repeating the step of measuring substantially at the same time a temperature value T_M of said compressor and a current value i_M of said compressor electric motor while said motor is in operation at a given electrical frequency.

[0076] The measurements of the current absorbed by the compressor and the compressor temperature are preferably performed continuously during the cycle of washing and/or drying to continuously check the working conditions of the compressor.

[0077] Preferably, in case an OLP is present in the laundry appliance, then the measurements of current and temperature are taken only after a transient regime in which the heat pump "warms up". Alternatively, the measurements can be taken only after the temperature of refrigerant or of the compressor has reached a lower threshold. In case there is no OLP in the laundry appliance, preferably the temperature and current measure-

ments are taken immediately after the drying cycle has started because the risk of anomalous current peaks is present and the OLP is not available to switch OFF the power supply.

[0078] Preferably, the method includes:

- Storing a first curve in the form $i_{MAX} = f(T_M)$ and T is continuous; and
- Storing a second curve in the form $T_{MAX} = g(i_M)$ and i is continuous.

[0079] A preferred method is thus storing curves in a continuous form, i.e. without solution of continuity, for example in the control unit of the appliance.

[0080] The temperature sensor can be for example a NTC or PCT thermistor.

[0081] Advantageously, said temperature sensor is located, in the drying appliance, at a refrigerant outlet provided on said compressor or on a part of a housing shell of said compressor.

[0082] The temperature sensor is located in a position where it can best determined the temperature of the compressor. With temperature of the compressor also the temperature of the refrigerant flowing in the compressor can be meant. In order to measure such temperature, the sensor is either located at the refrigerant outlet to measure the temperature of the refrigerant, or within the housing shell of the compressor, in particular at a part of such shell which is more subject to heat. The housing shell of the compressor houses the compressor, its electric motor and the compression devices to compress the refrigerant.

[0083] Preferably, the drying appliance includes an overload protector, said plurality of data or continuous curve being a characteristic curve of said overload protector. Said characteristic curve may be either the minimum curve or the maximum curve which envelop the OLP tripping strip. Alternatively, the laundry appliance includes a compressor which is free from an overload protector.

[0084] As already mentioned, the control on the temperature of the compressor and current absorbed by the compressor electric motor may be a further safety in addition to the OLP or a substitute to the OLP itself. In the first case, the OLP tripping is prevented and further in case of a malfunctioning of the control, the OLP intervenes; in the second case the removal of a component in the appliance is achieved, reducing costs and complexity of assembly.

[0085] Advantageously, said laundry appliance comprises a further electric motor to drive into rotation said treating chamber and/or a blower, or, in general, a pumping device, propelling said process medium.

[0086] Commonly, a dryer without washing capabilities includes a single motor driving both the process air fan or blower and the treating chamber. On the other hand, preferably washer-dryer includes two different motors, one bringing into rotation the treating chamber, and the

other one for commanding the blower of the process air or process medium.

[0087] Preferably, the drying appliance includes an active switch commanded by said processing unit to cut off power to said compressor.

[0088] Preferably, the laundry appliance includes a variable speed compressor.

[0089] Active switch and/or variable speed compressor are possible means used to limit the power supply to the compressor itself. A complete cut off of the power is obtained by the activation of the switch, while a power reduction is obtained reducing the speed of the compressor.

Brief description of the drawings

[0090] The present invention will now be described with reference to the accompanying drawings that illustrate nonlimiting embodiments thereof, wherein:

- Figure 1 is a perspective view of a laundry dryer according to the invention;
- Figure 2 shows a perspective view with a portion of the casing removed of the laundry dryer of Figure 1;
- Figure 3 is a perspective view, with parts removed, of the basement of the laundry dryer of Figure 1 showing in detail the closed-circuit, heat-pump type hot-air generator of the laundry dryer;
- Figure 4 is a schematic representation of the working principle of a heat-pump dryer according to the invention;
- Figure 5 is a graph of the compressor temperatures vs. absorbed current below which the compressor works under safety conditions;
- Figure 6 is a flow chart of a method of operation of the dryer of the invention; and
- Figure 7 is a portion of a flow chart of a variant of the method of operation of the dryer of the invention.

Detailed description of one or more embodiments of the invention

[0091] With initial reference to Figs. 1 and 2, a laundry dryer realized according to the present invention is globally indicated with 1.

[0092] Although the present description refers to a dryer, the laundry appliance of the invention could comprise a dryer, a washer-dryer or a washing machine.

[0093] Laundry dryer 1 comprises an outer box or casing 2, preferably but not necessarily parallelepiped-shaped, and a treating 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 2, so that it can rotate around a preferably horizontal axis R (in alternative embodiments, rotation axis may be tilted). Access to the drum 3 is achieved for example via a door 4, preferably hinged to casing 2, which

can open and close an opening 4a realized on the casing itself.

[0094] More in detail, casing 2 generally includes a front wall 20, a rear wall 21 and two lateral walls 25, all mounted on a basement 24. Preferably, the basement 24 is realized in polymeric material. Preferably, basement 24 is molded via an injection molding process. Preferably, on the front wall 20, the door 4 is hinged so as to access the drum. The casing, with its walls, defines the volume of the laundry dryer 1. Advantageously, basement 24 includes an upper and a lower shell portion 24a, 24b (visible in Figure 3 detailed below).

[0095] The dryer 1, and in particular basement 24, defines an horizontal plane (X,Y) which is substantially the plane of the ground on which the dryer 1 is situated, thus it is considered to be substantially horizontal, and a vertical direction Z perpendicular to the plane (X,Y).

[0096] Laundry dryer 1 also preferably comprises an electrical motor assembly 50 for rotating, on command, revolving drum 3 along its axis inside casing 2. Motor 50 includes a shaft 51 which defines a motor axis of rotation M (see figure 3).

[0097] Further, laundry dryer 1 may include an electronic control unit 100 (visible in figure 4) which controls both the electrical motor assembly 50 and other components of the dryer 1 to perform, on command, one of the user-selectable drying cycles preferably stored in the same control unit. The programs as well other parameters of the laundry dryer 1, or alarm and warning functions can be set and/or visualized in a control panel 11, preferably realized in a top portion of the dryer 1, such as above door 4. The control unit 100 may comprise one or more printed control boards.

[0098] With reference to Figure 2, the rotatable drum 3 includes a mantle, having preferably a substantially cylindrical, tubular body, which is preferably made of metal or polymeric material and is arranged inside the casing 2 and apt to rotate around the general rotational axis R which can be - as said - horizontal, i.e. parallel to the (X, Y) plane, or tilted with respect to the latter.

[0099] Drum 3 may be an open drum, i.e. with both ends are open, or it may include a back wall (not shown in the appended drawings) fixedly connected to the mantle and rotating with the latter.

[0100] In order to rotate, support elements for the rotation of the drum are provided as well in the laundry of the invention. Such support elements might include rollers at the front and/or at the back of the drum, as well as or alternatively a shaft connected to the rear end of the drum (shaft is not depicted in the appended drawings). In Fig. 2, for example, a roller 10 connected to the basement via a boss 101 is depicted. Any support element for the rotation of the drum around axis R is encompassed by the present invention.

[0101] Dryer 1 additionally includes a process air circuit which comprises the drum 3 and an air process conduit 18, depicted as a plurality of arrows showing the path flow of a process air stream through the dryer 1 (see

Figures 3 and 4). In the basement 24, a portion of the air process conduit 18 is formed by the connection of the upper shell 24a and the lower shell 24b. Air process conduit 18 is preferably connected with its opposite ends to the two opposite sides of drum 3, i.e. first and second end of mantle. Process air circuit also includes a fan or blower 12 (shown in Figs. 3 and 4).

[0102] A dedicated motor can be coupled to the fan 12, but in a possible simpler implementation the same motor can operate the fan 12 and the drum 3 (in other words only one of the two motors can be present, such as motor 50).

[0103] With now reference to figs. 3 and 4, the dryer 1 of the invention additionally comprises a process air generator, in the depicted embodiment a heat pump system 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 (partly depicted) 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 warms up, in correspondence of the second heat exchanger (evaporator) 32, absorbing heat. A compressor receives refrigerant in a gaseous state from the evaporator 32 and supplies the condenser 31, thereby closing the refrigerant cycle. In the following the heat exchangers are named either condenser and evaporator or first and second heat exchanger, respectively. More in detail, the heat pump circuit connects via piping 35 (see Fig. 3) the second heat exchanger (evaporator) 32 via a compressor 33 to the condenser 31. The outlet of condenser 31 is connected to the inlet of the evaporator 32 via an expansion device 103, such as a choke, a valve or a capillary tube.

[0104] Compressor 33 is driven by an electric motor (not visible in the figures), preferably integrated with the compressor in the same housing. Preferably, the compressor is a variable speed compressor so that the compressing velocity can be modified.

[0105] Preferably, in correspondence of evaporator 32, the laundry dryer 1 of the invention may include a condensed-water canister (also not visible) which collects the condensed water produced, when the dryer 1 is in operation, inside evaporator 32 by condensation of the surplus moisture in the process air stream arriving from the drying chamber (i.e. drum) 3. The canister is located at the bottom of the evaporator 32. Preferably, through a connecting pipe and a pump (not shown in the drawings), the collected water is sent in a reservoir located in correspondence of the highest portion of the dryer 1 so as to facilitate a comfortable manual discharge of the water by the user of the dryer 1.

[0106] The condenser 31 and the evaporator 32 of the heat pump 30 are located in correspondence of the process air conduit 18 formed in the basement 24.

[0107] In case of a condense-type dryer - as depicted in the appended figures - where the air process circuit is a closed loop circuit, the condenser 31 is located down-

stream of the evaporator 32. The air exiting the drum 3 enters the conduit 18 and reaches the evaporator 32 which cools down and dehumidifies the process air. The dry cool process air continues to flow through the conduit 18 till it enters the condenser 31, where it is warmed up by the heat pump 30 before re-entering the drum 3.

[0108] It is to be understood that in the dryer 1 of the invention, an air heater, such as an electrical heater, can also be present, in addition to the heat pump 30. In this case, heat pump 30 and heater can also work together to speed up the heating process (and thus reducing the drying cycle time).

[0109] Preferably, a cooling fan 38 is provided to cool down the compressor 33 (the cooling fan is schematically depicted in fig. 4). The cooling fan 38 may for example draw air from the outside of the casing 2 and blow it towards the compressor 33.

[0110] The control unit 100 preferably operates the compressor cooling fan 38 and the process fan 12. Further, control unit 100 preferably receives information by a monitoring system for monitoring the status of the compressor. For example, the control unit 100 can be electrically connected to a sensor 39 to detect the temperature of the refrigerant or of the compressor and/or to a sensing circuit 37 to detect a value and/or a change of potential and/or current absorbed by the compressor's electric motor. The sensing circuit 37 is for example integrated in the compressor 33 or in the control unit 100 itself.

[0111] Further, the temperature sensor 39, also connected to the control unit 100, is used to measure the value of the temperature of the compressor, which can be also the temperature of the flowing refrigerant. In particular an NTC thermistor is placed in such a way to measure the compressor temperature at the refrigerant outlet from the compressor, or within the same compressor housing where also the compressor electric motor is included. Additionally or alternatively, the temperature sensor 39 can be arranged at different location of the heat pump system.

[0112] Therefore, a signal having a value from which the temperature of the compressor can be derived and a signal having a value from which a value of the current absorbed by the motor of the compressor can be derived are sent to the control unit 100 by the temperature sensor 38 and the sensing circuit 37, respectively.

[0113] These values are used according to the method of the invention as depicted in figure 6.

[0114] The control unit 100 includes one or more memories (not shown), including a curve delimiting a safety area for the compressor, that is a curve which delimits the safety working field for the compressor. This curve is parametrized by

$i_{MAX}(T) = f(T)$ where i_{MAX} and T are forming couples of continuous values representing the maximum current which the compressor electric motor can absorb as a function of the compressor temperature, or

$T_{MAX}(i) = g(i)$ where T_{MAX} and i are forming couples of

continuous value representing the maximum temperature reachable by the compressor as a function of the current absorbed by the compressor's motor.

[0115] The storing of such a curve represent the step 1F of the method depicted in fig. 6.

[0116] Preferably, the control unit 100 monitors the status of the compressor 33 monitoring the temperature and current values coming from the aforementioned sensors 37 and 39. Each appliance 1 has a curve such the one above written stored in the memory of the control unit 100, and which depends on compressor 33 and on a selected predetermined safety field for the compressor. The curve can have a shape such the one depicted in figure 5, however any shape and trend is possible as long as the compressor is within the predetermined safety working area when working below this delimiting curve.

[0117] According to a preferred embodiment of the present invention, the measured temperature and current values obtained in a step 2F of the method, or the values from which the temperature of the compressor and the absorbed current of the motor of the compressor can be derived, are compared with the stored curve, as depicted in step 3F of figure 6.

[0118] If the temperature and current measurements identify a point in the (i,T) space above such a stored curve (see step 4F), then the power to the compressor (in particular to its motor) is limited because it means that the compressor is overheated (step 5F). If not, that is, if the point of the measured values (T_M , i_M) identify a point below such a stored curve, then the compressor in working under safe conditions and the cycle of the laundry appliance can continue and the measurement of the current and the temperature of the compressor can continue in order to keep the checking of the compressor's status.

[0119] The limitation of the power supply can be a complete cut off of the power to the compressor, for example, by means of a switch (not depicted in the drawings) or a reduction of the speed of the electric motor of the compressor.

[0120] According to a variant of the embodiment of the invention, the method replaces step 4F as modified according to figure 7, where step 4aF is depicted. The remaining steps of the method remains unchanged and are those of figure 6. In variant step 4aF, the check between the stored curve and the measured values of temperature and current is performed with respect to a "shifted" stored curve, that is, the limitation of the power supply to the compressor is made if the measured point (T_M , i_M) exceeds a shifted curve defined by:

point of the shifted curve (T_{shifted} , i_{shifted}) = point of stored curve (T , i) - (T_{safety} , i_{safety})

which is below the stored curve.

T_{safety} , i_{safety} are constant. In this embodiment a further safety is introduced.

Claims

1. A method to operate a laundry washing and/or drying appliance (1) including

- A treating chamber where laundry is introduced and treated with a process medium;
- a heat pump system (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 an electric motor, 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:

- storing a plurality (j) of data couples, a first element of each data couple being function of a maximum current value i_{MAXj} for the compressor electric motor current, and the second element of the couple being a corresponding function of a compressor maximum temperature value T_{MAXj} associated to the maximum current value i_{MAXj} of the first element, said plurality of data couples delimiting a predetermined safety work space for said compressor;
- measuring substantially at the same time a temperature value T_M representative of the temperature of said compressor and a current value i_M representative of the current absorbed by said electric motor of said compressor while said heat pump is in operation;
- comparing said measured temperature value T_M and said measured current value i_M with said plurality of data couples; and
- limiting power supply to said compressor if:

- there is a data couple (T_{MAXj^*} , i_{MAXj^*}) in said plurality for which $|T_{\text{MAXj}^*} - T_M| = \min_j (|T_M - T_{\text{MAXj}}|)$ and $i_M \geq i_{\text{MAXj}^*}$ or
- there is a data couple (T_{MAXj^*} , i_{MAXj^*}) in said plurality for which $|i_{\text{MAXj}^*} - i_M| = \min_j (|i_M - i_{\text{MAXj}}|)$ and $T_M \geq T_{\text{MAXj}^*}$.

2. Method according to claim 1, wherein limiting power supply to said compressor comprises:

- switching OFF the compressor electric motor; or
- adjusting a rotational speed of the compressor electric motor.

3. Method according to claim 1 or 2, further comprising:

• Providing a compressor cooling fan in proximity of said compressor; and, if said power to said compressor has been cut, one or more of:

- Switching ON said compressor cooling fan;
- adjusting an upper threshold temperature of the refrigerant for driving the switching ON of said compressor cooling fan;
- adjusting a lower threshold temperature of the refrigerant for driving the switching OFF of said compressor cooling fan;
- adjusting a rotational speed of a compressor cooling fan;
- adjusting an ON/OFF ratio of said compressor cooling fan.

4. Method according to one or more of the preceding claims, wherein said process medium is drying air flowing in a process drying air circuit and said apparatus is apt to dry items, comprising:

• Providing a process fan to move air within said process air drying circuit; and, if said power to said compressor has been cut, one or more of:

- Switching ON, or keeping switched ON said process fan;
- adjusting a rotational speed of said process fan.

5. Method according to one or more of the preceding claims, further comprising:

adjusting a rotational speed and/or a clockwise/counterclockwise rotation ratio of a motor adapted to drive into rotation the treating chamber.

6. Method according to one or more of the preceding claims, comprising:

- Setting a threshold safety value i_{safety} ;
- And wherein comparing said measured temperature value T_M and said measured current value i_M with said plurality of data couples includes:
- Comparing said measured temperature value T_M with said plurality of data couples;
- Determining a data couple (T_{MAXj^*}, i_{MAXj^*}) for which $|T_{MAXj^*} - T_M| = \min_j(|T_M - T_{MAXj}|)$;
- comparing a maximum current value i_{MAXj^*} of said data couple corresponding to the determined closest maximum temperature value T_{MAXj^*} to the measured current value i_M ;
- limiting power supply to said compressor if $|i_{MAXj^*} - i_M| \leq i_{safety}$.

7. Method according to one or more of the preceding claims, comprising:

- Setting a threshold safety value T_{safety} ;
- And wherein comparing said measured temperature value T_M and said measured current value i_M with said plurality of data couples includes:
- Comparing said measured current value i_M with said plurality of data couples;
- Determining a data couple (T_{MAXj^*}, i_{MAXj^*}) for which $|i_{MAXj^*} - i_M| = \min_j(|i_M - i_{MAXj}|)$;
- comparing a maximum temperature value T_{MAXj^*} of said data couple corresponding to the determined closest maximum current value i_{MAXj^*} to the measured temperature value T_M ;
- limiting power supply to said compressor if $|T_{MAXj^*} - T_M| \leq T_{safety}$.

8. Method according to one or more of the preceding claims, including any of:

- Switching ON again said compressor after a predetermined time is elapsed from the switching OFF of the compressor motor;
- Restore the compressor power supply as it was before the power supply limitation was made; or
- Supplying said compressor with a power which depends on a selected drying cycle when said measured temperature value T_M is below a predetermined threshold.

9. Method according to one or more of the preceding claims, comprising:

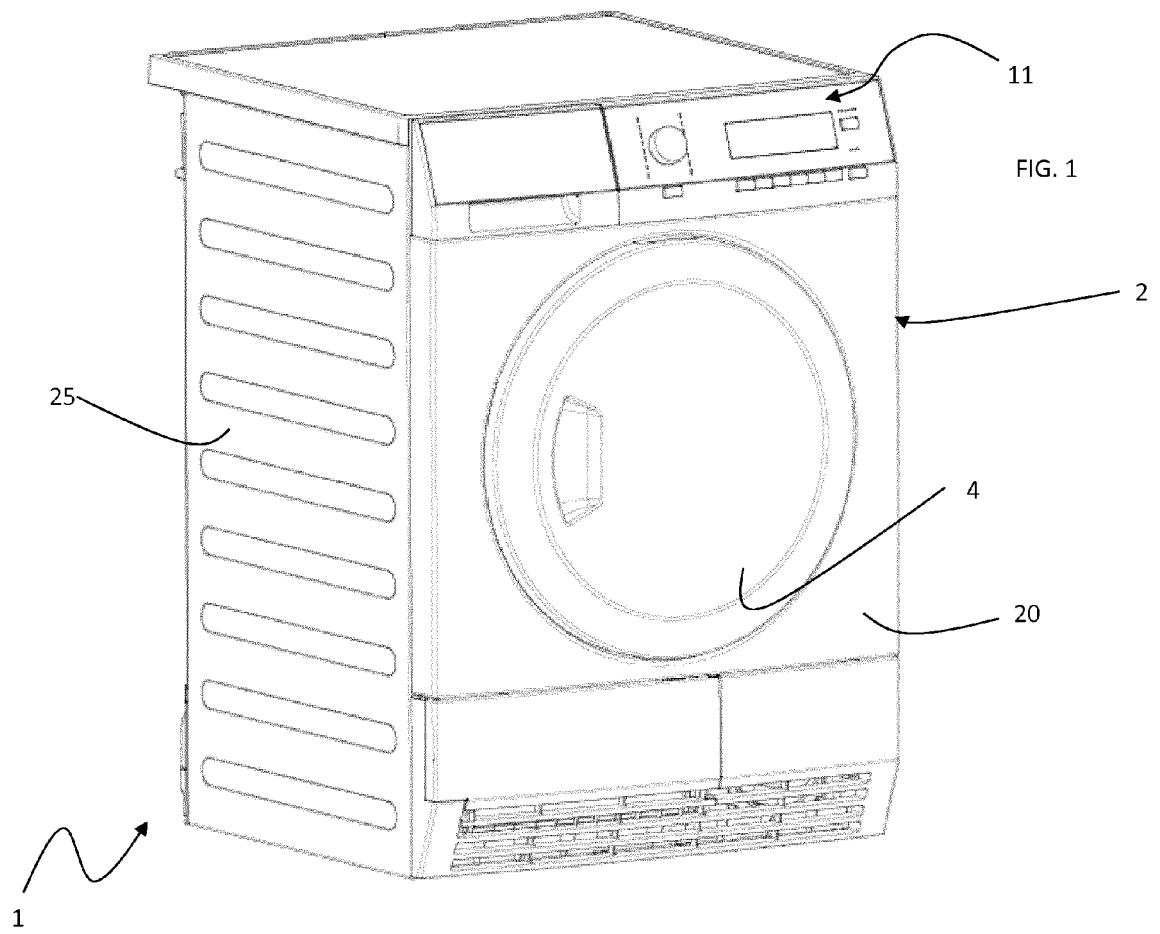
- Repeating the step of measuring substantially at the same time a temperature value T_M of said compressor and a current value i_M of the compressor electric motor while said motor is in operation at a given electrical frequency.

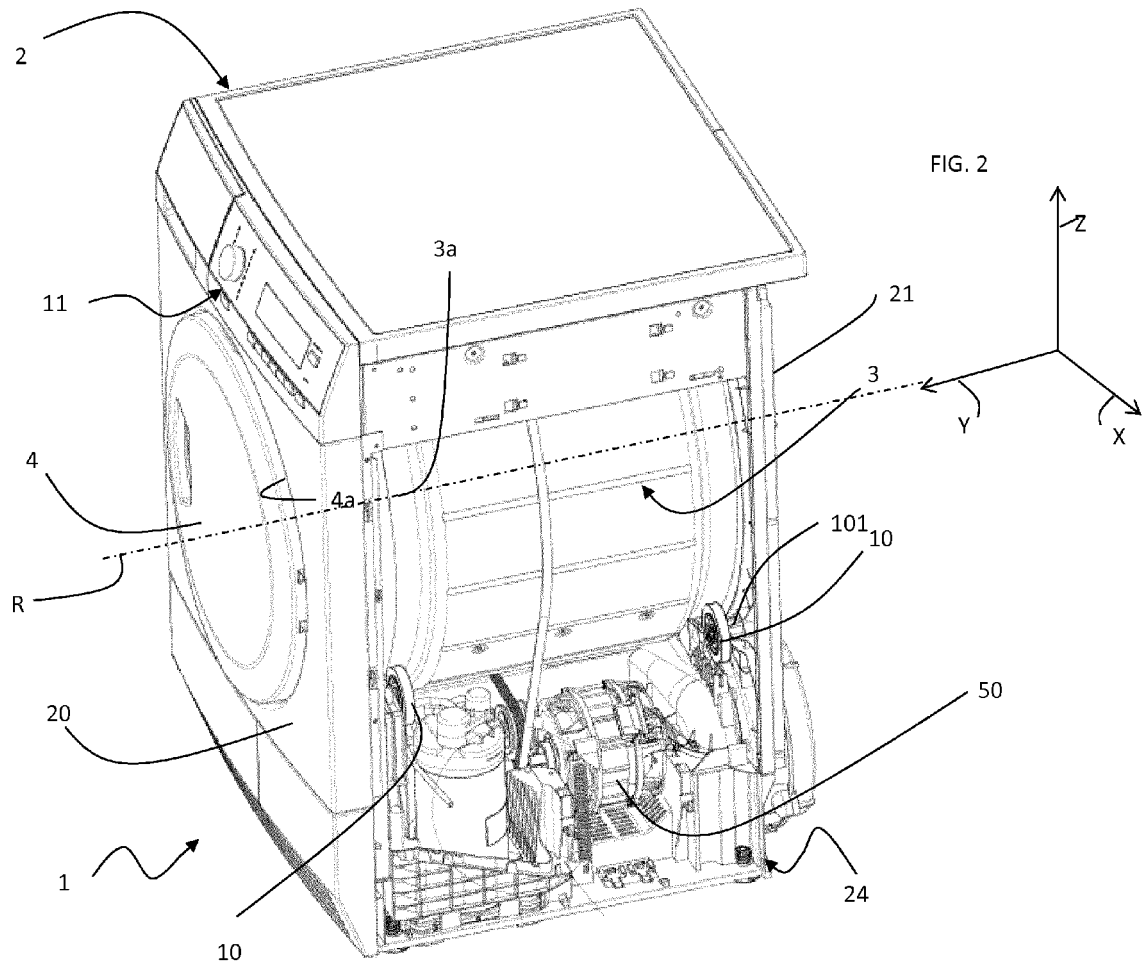
10. Method according to one or more of the preceding claims, wherein storing a plurality (j) of data couples, a first element of each data couple being function of a maximum current value i_{MAXj} for the compressor electric motor current, and the second element of the couple being a corresponding function of a compressor maximum temperature value T_{MAXj} associated to the maximum current value i_{MAXj} of the first element, said plurality of data couples delimiting a safety working space for said compressor; includes:

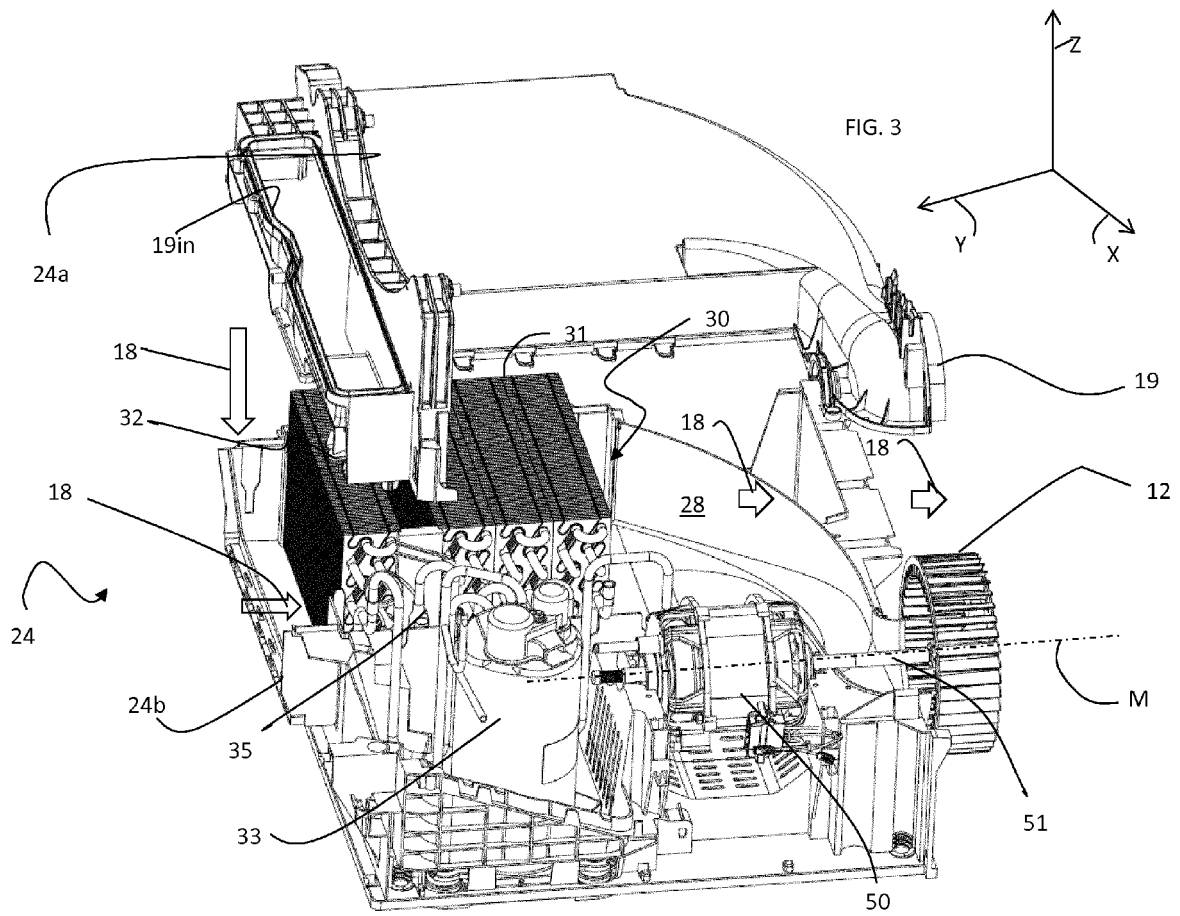
Storing a first curve in the form $i_{MAX} = f(T_M)$ and T_M is continuous; and
Storing a second curve in the form $T_{MAX} = g(i_M)$ and i_M is continuous.

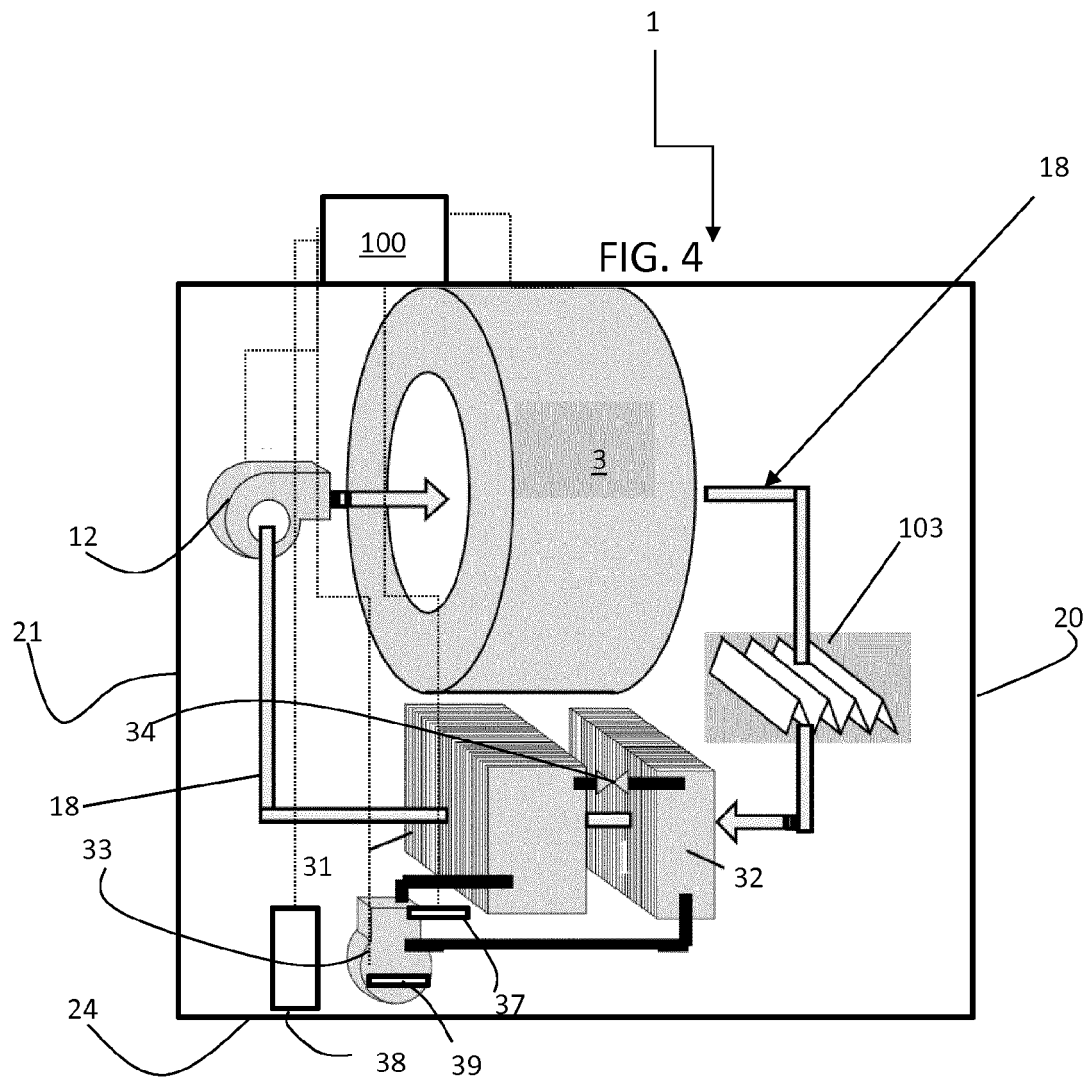
11. A laundry washing and/or drying appliance including:

- A treating chamber where laundry is introduced and treated with a process medium;
 - A heat pump system (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 an electric motor, 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 memory storing a plurality (j) of data couples, a first element of each data couple being function of a maximum current value i_{MAXj} for an electric motor current, and the second element of the couple being a corresponding function of a compressor maximum temperature value T_{MAXj} associated to the maximum current value i_{MAXj} of the first element, said plurality of data couples delimiting a predetermined safety work space for said compressor;
 - A temperature sensor and a current sensor apt to measure substantially at the same time a value indicative of a temperature of said compressor and a value indicative of an absorbed current of said compressor electric motor, respectively;
 - A processing unit (40) apt to receive a signal sent by said temperature sensor and a signal sent by current sensor (39) based on said measured values; said processing unit (40) being able to compare said signals based on said measured temperature value T_M and said absorbed current value i_M with said plurality of data; and to limit power supply to said compressor if There is a data couple (T_{MAXj^*}, i_{MAXj^*}) in said plurality for which $|T_{MAXj^*} - T_M| = \min_j (|T_M - T_{MAXj}|)$ and $i_M \geq i_{MAXj^*}$ or There is a data couple (T_{MAXj^*}, i_{MAXj^*}) in said plurality for which $|i_{MAXj^*} - i_M| = \min_j (|i_M - i_{MAXj}|)$ and $T_M \geq T_{MAXj^*}$.
12. The laundry appliance (1) of claim 11, wherein said temperature sensor is located at a refrigerant outlet provided on said compressor or on a part of a housing shell of said compressor (33).
13. The laundry appliance (1) of claim 11 or 12, including an overload protector, said plurality of data or continuous curve being a characteristic curve of said overload protector.
14. The laundry appliance of any of claims 11 - 13, including an active switch commanded by said processing unit to cut off power to said compressor
- (33).
15. The laundry appliance (1) of claim 11 or 12, wherein said compressor (33) is free from an overload protector.
16. The laundry appliance (1) of any of claims 11 - 15, wherein said apparatus comprises a further electric motor to drive into rotation said treating chamber and/or a pumping device propelling said process medium.
17. The laundry appliance (1) according to any of claims 11 - 16, including a variable speed compressor (33).









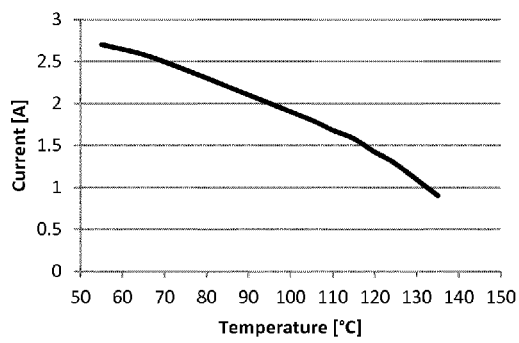


FIG. 5

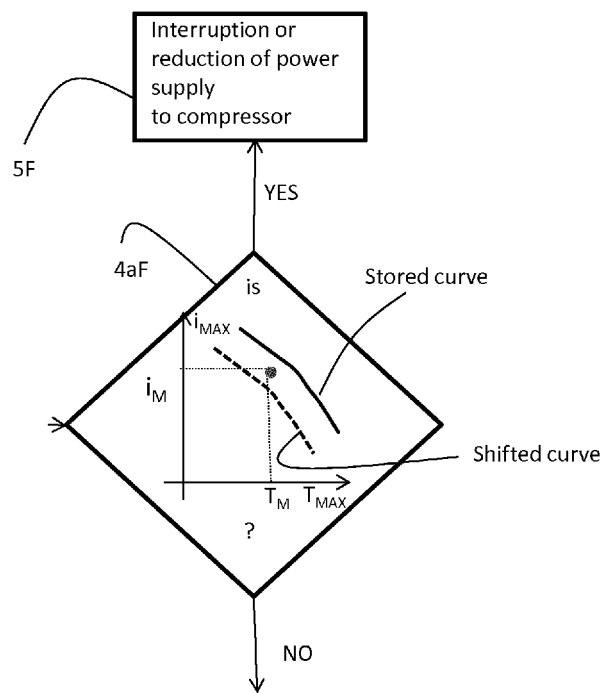


FIG. 7

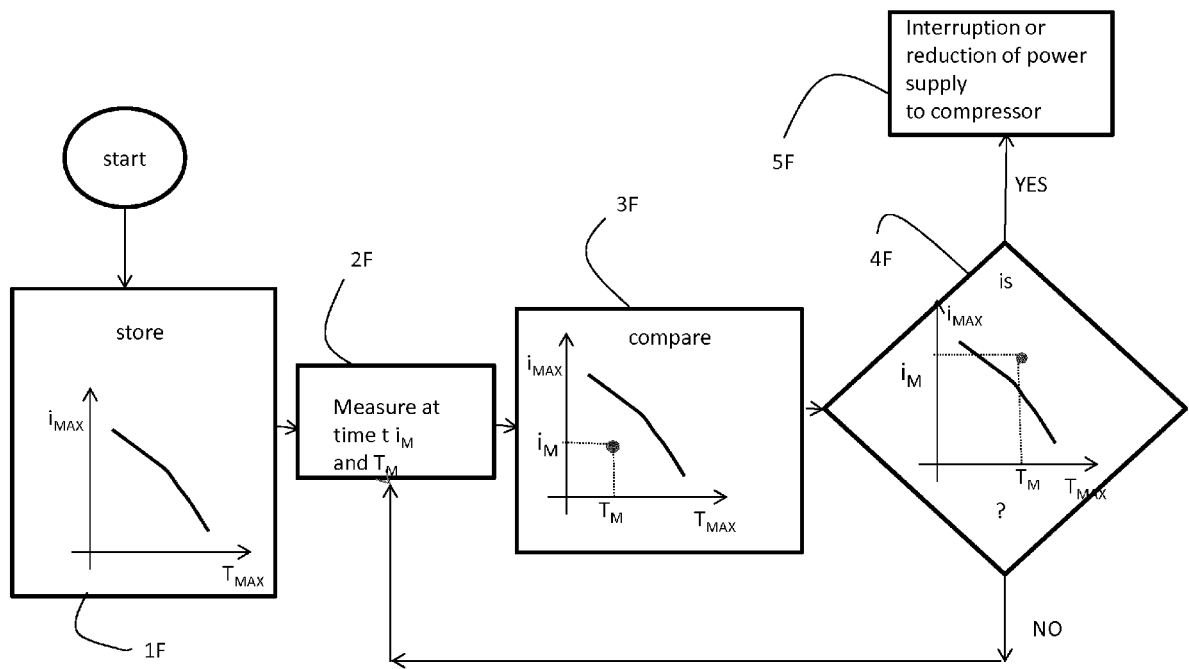


FIG. 6



EUROPEAN SEARCH REPORT

Application Number
EP 15 17 8405

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	EP 2 679 718 A1 (ELECTROLUX HOME PROD CORP [BE]) 1 January 2014 (2014-01-01) * paragraphs [0034], [4238], [0039] *	1-3,11	INV. D06F58/20 D06F58/28
A	WO 2009/020322 A2 (LG ELECTRONICS INC [KR]; MOON JUNG WOOK [KR]; PARK DAE YUN [KR]; HONG) 12 February 2009 (2009-02-12) * paragraphs [0081] - [0098]; figures 3,4 *	1,3,11,12	
A	EP 2 843 118 A1 (ELECTROLUX APPLIANCES AB [SE]) 4 March 2015 (2015-03-04) * paragraphs [0051], [0052]; figures 1,3 *	1,11	
A	JP 2008 099984 A (MATSUSHITA ELECTRIC IND CO LTD) 1 May 2008 (2008-05-01) * abstract *	1,11	
			TECHNICAL FIELDS SEARCHED (IPC)
			D06F
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 12 January 2016	Examiner Kising, Axel
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03/02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 15 17 8405

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

12-01-2016

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2679718 A1	01-01-2014	AU 2013283593 A1	15-01-2015
		CN 104583483 A	29-04-2015
		EP 2679718 A1	01-01-2014
		EP 2867400 A1	06-05-2015
		WO 2014001114 A1	03-01-2014

WO 2009020322 A2	12-02-2009	EP 2191057 A2	02-06-2010
		KR 20090014054 A	06-02-2009
		US 2011005097 A1	13-01-2011
		WO 2009020322 A2	12-02-2009

EP 2843118 A1	04-03-2015	NONE	

JP 2008099984 A	01-05-2008	JP 4615500 B2	19-01-2011
		JP 2008099984 A	01-05-2008
