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(54) **A method for controlling a heat pump system for a laundry drying machine and a corresponding laundry drying machine**

(57) The present invention relates to a method for controlling a laundry drying machine of the type comprising a heat pump system having a refrigerant circuit (30) for a refrigerant and comprising an air stream circuit (10) including at least one laundry drum (9) for receiving laundry to be dried. The refrigerant circuit (30) comprises a compressor (24) with a variable rotation speed, a first heat exchanger for a thermal coupling between said air stream circuit (10) and said refrigerant circuit (30) and a second heat exchanger (23) for a further thermal coupling between said air stream circuit (10) and said refrigerant circuit (30).

The method comprises the steps of:

- determining the amount of load (W) in the laundry drum (9); and
- controlling the average speed (V) or the average power (P) of the compressor (24) in a drying cycle according to the amount of load (W), so that in case of a first amount of load (W) the average speed (V) or the average power (P) of the compressor (24) is set to a first operational value (Vh) and in case of a second amount of load (W) the average speed (V) or the average power (P) of the compressor (24) is set to a second operational value (Vf). The first amount of load (W) is smaller than the second amount of load (W) and the first operational value (Vh) is higher than the second operational value (Vf).

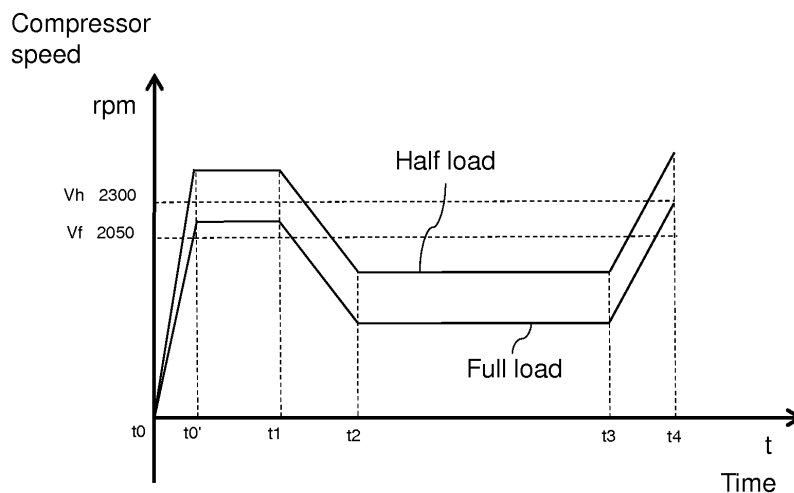


FIG. 7

**Description**

[0001] The present invention concerns the field of laundry drying techniques.

[0002] In particular, the present invention refers to a laundry drying machine equipped with a heat pump system and, more in particular, a method for controlling such a heat pump system.

**BACKGROUND ART**

[0003] Laundry treating machines capable of carrying out a drying process on laundry, hereinafter simply indicated as laundry dryers, generally comprise a casing that houses a laundry container, like a rotating drum, where laundry to be treated is received. A closed air stream circuit carries out drying operation by circulating hot air through the laundry container containing the wet laundry.

[0004] In laundry dryers, the heat pump technology is the most efficient way to save energy during drying operation. In conventional heat pump laundry dryers a drying air stream flows in a close loop. The drying air stream is moved by a fan, passes the laundry drum and removes water from wet clothes. Then the drying air stream is cooled down and dehumidified and then heated up in a heat pump system and finally reinserted again into the laundry drum.

[0005] The heat pump system comprises a refrigerant flowing in a closed-loop refrigerant circuit constituted by a compressor, a condenser, an expansion device and an evaporator. The condenser heats up the drying air while the evaporator cools and dehumidifies the drying air leaving the drum. The refrigerant flows in the refrigerant circuit where it is compressed by the compressor, condensed in the condenser, expanded in the expansion device and then vaporized in the evaporator. The temperatures of the drying air stream and the refrigerant are strongly correlated to each other.

[0006] Laundry dryers of known type with a heat pump technology typically uses a fixed speed compressor for the refrigerant circuit. The choice of the compressor is affected by space constraints. The size of the compressor and then the heating and cooling capacity are limited. Moreover, with a fixed speed compressor, the heat pump system can be adapted to different kind of cycles or to different working conditions of the system that occur during the drying cycle: this type of compressor works in an on/off-mode, so that the operating parameters of said compressor and of the heat pump system cannot be controlled during the operation.

[0007] DE 10 2005 041 145 A1 discloses a laundry dryer with a heat pump system. The refrigerant circuit of said heat pump system includes a compressor with a variable output power. The output power of the compressor depends either on detected parameters or on a predetermined scheme.

[0008] It is an object of the present invention to provide a method for controlling a heat pump system for a laundry dryer which allows an additional saving of energy during the drying cycle.

**DISCLOSURE OF INVENTION**

[0009] The applicant has found that by providing a method for controlling a laundry drying machine with at least one heat pump system comprising an air stream circuit including at least one drum for receiving laundry to be dried, at least one refrigerant circuit including at least one compressor with a variable rotation speed, a first heat exchanger for a thermal coupling between the air stream circuit and the refrigerant circuit and a second heat exchanger for a further thermal coupling between the air stream circuit and the refrigerant circuit, wherein the average speed or the average power of said compressor in a drying cycle is controlled according to the amount of load, it is possible to save energy during the drying cycle.

[0010] In a first aspect the present invention relates, therefore, to a method for controlling a laundry drying machine of the type comprising a heat pump system having a refrigerant circuit for a refrigerant and comprising an air stream circuit including at least one laundry drum for receiving laundry to be dried, said refrigerant circuit comprising:

- a compressor with a variable rotation speed;
- a first heat exchanger for a thermal coupling between said air stream circuit and said refrigerant circuit wherein the temperature of said air stream increases and the temperature of said refrigerant decreases; and
- a second heat exchanger for a further thermal coupling between said air stream circuit and said refrigerant circuit wherein the temperature of said air stream decreases and the temperature of said refrigerant increases; wherein said method comprises the steps of:
  - determining the amount of load in said laundry drum; and
  - controlling the average speed or the average power of said compressor in a drying cycle according to said amount of load, so that in case of a first amount of load said average speed or said average power of said compressor is set to a first operational value and in case of a second amount of load said average speed or said average power of said compressor is set to a second operational value, wherein said first amount of load is smaller than said second

amount of load and said first operational value is higher than said second operational value.

**[0011]** In a preferred embodiment of the invention, the step of determining the amount of load in the laundry drum includes receiving information about the amount of load through a user selection of data.

**[0012]** Preferably, the step of receiving information about the amount of load through a user selection of data comprises acting on a button or on a selector of a user interface of the laundry drying machine.

**[0013]** In a further preferred embodiment of the invention, the step of determining the amount of load in the laundry drum includes detecting and/or estimating the amount of load in the laundry drum.

**[0014]** Preferably, the step of detecting and/or estimating the amount of load in the laundry drum comprises the step of evaluating working parameters of the laundry drying machine.

**[0015]** In a preferred embodiment of the invention, the step of evaluating working parameters of the laundry drying machine comprises the step of detecting the weight of the load by means of a weight sensor associated to the laundry drum. In another preferred embodiment of the invention, the step of evaluating working parameters of the laundry drying machine comprises the step of measuring the electrical parameters of an electric drum motor.

**[0016]** Preferably, the step of measuring the electrical parameters of an electric drum motor comprises the step of measuring the electric current and/or the induced voltage of said electric drum.

**[0017]** In another preferred embodiment of the invention, the step of evaluating working parameters of the laundry drying machine comprises the step of measuring the mechanical parameters of an electric drum motor.

**[0018]** Preferably, the step of measuring the mechanical parameters of an electric drum motor comprises the step of measuring the torque of said electric drum.

**[0019]** In another preferred embodiment of the invention, the step of evaluating working parameters of the laundry drying machine comprises the step of detecting the temperature of the air stream at an inlet and/or at an outlet of the laundry drum. In another preferred embodiment of the invention, the step of evaluating working parameters of the laundry drying machine comprises the step of detecting the temperature of the air stream at an inlet and/or at an outlet of said second heat exchanger.

**[0020]** In a further preferred embodiment of the invention, the step of evaluating working parameters of the laundry drying machine comprises the step of detecting the electric resistance and/or conductivity of wet laundry by means of a conductometric system.

**[0021]** Preferably, the method comprises the step of estimating the amount of load inside the laundry drum by evaluating the noise and/or fluctuation of the detected electric resistance and/or conductivity.

**[0022]** In a preferred embodiment of the invention, the step of evaluating the noise and/or fluctuation of the detected electric resistance and/or conductivity comprises:

- measuring the value of peaks of an electric signal corresponding to the detected electric resistance and/or conductivity, and/or
- measuring the number of peaks within a time span of an electric signal corresponding to the detected electric resistance and/or conductivity, and/or
- measuring the area subtended by peaks of an electric signal corresponding to the detected electric resistance and/or conductivity.

**[0023]** Preferably, the conductometric system comprises at least two electrodes suitable to contact the laundry inside the laundry drum.

**[0024]** In a preferred embodiment of the invention, the step of determining the amount of load in the laundry drum is carried out within a predetermined time interval at the beginning of the drying cycle.

**[0025]** In a first preferred embodiment of the invention, the step of determining the amount of load in the laundry drum is carried out before the activation of the compressor.

**[0026]** In a second preferred embodiment of the invention, the step of determining the amount of load in the laundry drum is carried after the activation of the compressor.

**[0027]** Preferably, the step of determining the amount of load in the laundry drum is carried out after said laundry drum starts to rotate.

**[0028]** In a first preferred embodiment of the invention, at least one predetermined threshold value for the amount of load is defined, wherein above the threshold value the average speed or the average power of the compressor is set to the second operational value and below the threshold value the average speed or the average power of the compressor is set to the first operational value.

**[0029]** In a second preferred embodiment of the invention, two or more ranges for the amount of load are defined and corresponding two or more operational values of the average speed or of the average power of the compressor are set, wherein if the amount of load is comprised in a first range which has smaller values than the values of a second range then the correspondent first operational value of the average speed or of the average power of the compressor is set at

an operational value higher than the correspondent second operational value of the average speed or of the average power of the compressor.

[0030] In a preferred embodiment of the invention, the drying cycle is performed at a steady compressor speed or at a steady compressor power.

[0031] In a further preferred embodiment of the invention, the drying cycle is performed at a variable compressor speed or at a variable compressor power.

[0032] Preferably, the drying cycle comprises a first phase at a higher compressor speed or at a higher compressor power than a successive phase.

[0033] Preferably, the drying cycle comprises a final phase at a higher compressor speed or at a higher compressor power than a previous phase.

[0034] Preferably, the drying cycle comprises a phase wherein the compressor speed or the compressor power increases.

[0035] In a further aspect the present invention relates to a laundry drying machine suited to implement the method above described.

[0036] Preferably, the laundry drying machine comprises a heat pump system comprising:

- an air stream circuit including at least one drum for receiving laundry to be dried;
- at least one refrigerant circuit including at least one compressor with a variable rotation speed, a first heat exchanger for a thermal coupling between the air stream circuit and the refrigerant circuit and a second heat exchanger for a further thermal coupling between the air stream circuit and the refrigerant circuit; and
- a central processing unit provided for determining the amount of load in said laundry drum, wherein the central processing unit is provided for controlling the average speed or the average power of said compressor in a drying cycle according to said amount of load so that in case of a first amount of load said average speed or said average power of said compressor is set to a first operational value and in case of a second amount of load said average speed or said average power of said compressor is set to a second operational value, wherein the first amount of load is smaller than the second amount of load and the first operational value is higher than the second operational value.

[0037] In a preferred embodiment of the invention, the laundry drying machine comprises a user interface having a button or a selector from which the user inputs the amount of load.

[0038] In a preferred embodiment of the invention, the laundry drying machine comprises a weight sensor associated to the laundry drum.

[0039] Preferably, the central processing unit measures the electric current and/or the induced voltage of an electric motor associated to the laundry drum.

[0040] In a further preferred embodiment of the invention, the laundry drying machine comprises a conductometric system.

[0041] Advantageously, the conductometric system comprises at least two electrodes arranged inside the laundry drum.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0042] Further characteristics and advantages of the present invention will be highlighted in greater detail in the following detailed description of preferred embodiments of the invention, provided with reference to the enclosed drawings. In said drawings:

- Figure 1 shows a perspective view of a laundry drying machine with a heat pump system according to a preferred embodiment of the invention;
- Figure 2 illustrates a schematic diagram of the laundry drying machine of Figure 1;
- Figure 3 is a simplified flow chart of the basic operations of a method for drying laundry in the laundry drying machine of Figure 1 according to a first embodiment of the invention;
- Figure 4 illustrates a schematic diagram of the compressor speed as a function of the amount of load according to the preferred embodiment of the present invention;
- Figure 5 illustrates a schematic diagram of the compressor speed as a function of the time in a full-load condition of the laundry drying machine according to the preferred embodiment of the present invention;
- Figure 6 illustrates a schematic diagram of the compressor speed as a function of the time in a half-load condition of the laundry drying machine according to the preferred embodiment of the present invention;
- Figure 7 illustrates a schematic diagram of the compressor speed as a function of the time in a full-load condition and in a half-load condition according to a further preferred embodiment of the present invention;

- Figures from 7A to 7D illustrate further embodiments of the diagram of Figure 7;
- Figure 8 illustrates a schematic diagram of the compressor speed as a function of the amount of load according to a further preferred embodiment of the present invention;
- Figure 9 illustrates a schematic diagram of the compressor speed as a function of the time in different load conditions according to a further preferred embodiment of the present invention;
- Figure 10 illustrates a schematic diagram of the compressor speed as a function of the time in different load conditions according to a further preferred embodiment of the present invention;
- Figure 11 illustrates a schematic diagram of the compressor power as a function of the amount of load according to the preferred embodiment of the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

**[0043]** The present invention has proved to be particularly successful when applied to a front-loading laundry dryer with a rotatable laundry container; however it is clear that the present invention can be applied as well to a top-loading laundry dryer. Furthermore, the present invention can be usefully applied to all the machines requiring a drying phase for wetted clothes, as for example a combined laundry washing and drying machine.

**[0044]** In the present description the term "laundry drying machine" will refer to both simple laundry drying machines and laundry washing-drying machines.

**[0045]** Figures 1 and 2 illustrate a laundry drying machine 1, or laundry dryer, with a heat pump system 20 according to a first embodiment of the present invention.

**[0046]** The laundry dryer 1 preferably comprises, though not necessarily, a substantially parallelepiped-shaped outer boxlike casing 2 which is preferably structured for resting on the floor. A laundry container consisting of a rotatably drum 9 is provided within the casing 2. A front door 8, pivotally coupled to the front upright side wall 2a, is provided for allowing access to the drum interior region to place laundry to be dried therein.

**[0047]** The drum 9 is advantageously rotated by a drum motor, preferably an electric motor, which preferably transmits the rotating motion to the shaft of the drum 9, advantageously by means of a belt/pulley system. In a different embodiment of the invention, the drum motor can be directly associated with the shaft of the drum 9.

**[0048]** A user control interface 15 is preferably arranged on the top of the casing 2. The user control interface 15 is preferably accessible to the user for the selection of the drying cycle and insertion of other parameters, for example the type of fabric of the load, the degree of dryness, etc.. The user control interface 15 preferably displays machine working conditions, such as the remaining cycle time, alarm signals, etc. For this purpose the user control interface 15 preferably comprises a display 13.

**[0049]** In different embodiments, for example in a combined laundry washing and drying machine, the user may select and inserts other types of parameters, for example the washing temperature, the spinning speed, etc..

**[0050]** In further embodiments, the user control interface may be differently realized, for example remotely arranged in case of a remote-control system.

**[0051]** The laundry dryer 1 is provided with an air stream circuit 10, as illustrated in Figure 2, which is structured to circulate inside the drum 9 a stream of hot air. The hot air circulates over and through the laundry located inside the drum 9 to dry the laundry. The drum 9 itself is therefore part of the air stream circuit 10. The air stream circuit 10 is also structured for drawing moist air from the drum 9, cooling down the moist air leaving the drum 9 so to extract and retain the surplus moisture. The dehumidified air is then heated up to a predetermined temperature preferably higher than that of the moist air arriving from the drum 9. Finally the heated, dehumidified air is conveyed again into the drum 9, where it flows over and through the laundry stored inside the rotatable drum 9 to rapidly dry the laundry, as said above.

**[0052]** The air stream circuit 10 forms therefore a closed-loop for the air A, as schematically illustrated with dashed line in Figure 2.

**[0053]** A fan 12 is preferably arranged along the circuit 10 for generating the air stream A, more preferably upstream of the drum 9. The fan 12 is adapted and designed for circulating the air within the air stream circuit 10.

**[0054]** Preferably, and more particularly, the air stream circuit 10 comprises a dehumidifying unit 23 arranged downstream of the drum 9 and a heater unit 21 arranged downstream of the dehumidifying unit 23 and upstream of the drum 9. It is underlined that in the present application the terms "upstream" and "downstream" are referred to the flowing direction of the air, heated air and/or moist air, during the standard functioning of the laundry dryer; for example saying that the fan is arranged upstream of the drum means that in the standard functioning of the laundry dryer the air firstly passes through the fan and then flows into the drum; saying that the dehumidifying unit is arranged downstream of the drum means that in the standard functioning of the laundry dryer the air firstly circulates inside the drum and then passes through the dehumidifying unit. In the dehumidifying unit 23 the moist air cools down and condenses and the water generated therein is preferably collected in a removable container 14, visible in Figure 1, arranged below the dehumidifying unit 23.

**[0055]** In the preferred embodiment here described, the dehumidifying unit 23 is the evaporator of the heat pump

system 20 and the heating unit 21 is the condenser of said heat pump system 20.

[0056] Therefore, the evaporator 23 dehumidifies the moist air coming from the drum 9 and then the condenser 21 heats up the dehumidified air coming from the evaporator 23. The heated air is then conveyed again into the drum 9.

[0057] In further embodiments, the air stream circuit may not form a closed-loop. In this case, for example, the air stream may be conveyed to a condenser from outside, then conveyed into the drum, from the drum conveyed to the evaporator and finally expelled to the outside.

[0058] The heat pump system 20 with its evaporator 23 and condenser 21, therefore, interacts with the air stream circuit 10. In fact, the air stream circuit 10 and the heat pump system 20 are thermally coupled by the condenser 21 and the evaporator 23.

[0059] In particular, the heat pump system 20 advantageously comprises a refrigerant circuit 30 forming a closed-loop circuit where a refrigerant flows.

[0060] The refrigerant circuit 30 comprises a compressor 24, a first heat exchanger 21, i.e. the condenser 21 in the preferred embodiment here described, an expansion device 22 and a second heat exchanger 23, i.e. the evaporator 23 in the preferred embodiment here described. The compressor 24, the condenser 21, the expansion device 22 and the evaporator 23 are connected in series to form said closed-loop circuit.

[0061] The refrigerant flows in the refrigerant circuit 30 wherein is compressed by the compressor 24, condensed in the condenser 21, expanded in the expansion device 22 and then vaporized in the evaporator 23.

[0062] In different embodiments, the first heat exchanger may comprise a gas cooler (instead of the condenser) and the second heat exchanger may comprise a gas heater (instead of the evaporator). In this case the refrigerant is advantageously a gas, such as CO<sub>2</sub>, which maintains its gaseous state along all the closed-loop circuit, and in particular in the gas cooler and in the gas heater. In this type of heat pump system the gas temperature changes while passing through the gas cooler and the gas heater.

[0063] Generally, the first heat exchanger 21 defines a thermal coupling between the air stream circuit 10 and the refrigerant circuit 30 wherein the temperature of the air stream increases and the temperature of the refrigerant decreases.

[0064] Analogously, the second heat exchanger 23 defines a further thermal coupling between the air stream circuit 10 and the refrigerant circuit 30 wherein the temperature of the air stream decreases and the temperature of the refrigerant increases.

[0065] The portion of the refrigerant circuit 30 comprised between the compressor outlet 24b and the expansion device inlet 22a defines a high-pressure side wherein the refrigerant is compressed at a high pressure (for example 20-30 bars when the refrigerant used is R407c).

[0066] On the other hand, the portion of the refrigerant circuit 30 comprised between the expansion device outlet 22b and the compressor inlet 24a defines a low-pressure side wherein the refrigerant is expanded at a low pressure (for example 8-10 bars when the refrigerant used is R407c).

[0067] A control unit 26 is also provided for controlling the compressor 24. In particular, the control unit 26 is provided for controlling the rotation speed V of the compressor 24. The control unit 26 for controlling the rotation speed V of the compressor 24 can be part of a central processing unit, not illustrated.

[0068] It should be noted that with rotation speed V of the compressor 24 it is meant the rotation speed of a driving motor which is part of the compressor 24.

[0069] Further, the laundry dryer 1 may comprise several kinds of sensor elements, which are not shown in the figures. For example, the sensor elements may be provided for detecting the temperature, the relative humidity and/or the electrical impedance at suitable positions of the laundry dryer 1.

[0070] The central processing unit above mentioned is advantageously connected to the various parts of the dryer 1, or peripheral units, in order to ensure its operation. A first embodiment of the method for controlling the laundry dryer 1 according to the invention is described here below with reference to Figures from 3 to 6. The laundry to be dried is first placed inside the drum 9 (step 100 of Figure 3). By operating on the interface unit 15 the user selects the desired drying cycle (step 110) depending, for example, on the type of laundry textile to dry or on the dryness degree of the laundry which is expected at the end of the program, for example totally dried or with residual moisture for a best ironing.

[0071] Once the user has selected the desired drying cycle (step 110), the central processing unit sets the laundry drying machine 1 so that it starts the drying cycle.

[0072] In a further embodiment, the selection of the desired drying cycle (step 110) may be performed before placing the laundry into the drum 9 (step 100).

[0073] According to the invention, in a successive phase (step 120) the amount of load W is determined.

[0074] Determining the amount of load W in the laundry drum 9 includes detecting and/or estimating the amount of load W by evaluating predetermined working parameters of the laundry dryer, as will be better described later.

[0075] Further, determining the amount of load W in the laundry drum 9 includes receiving information about the amount of load W through a user selection of data.

[0076] A preferred way to determine the amount of load W by the user may include the provision of a button 17 on the user control interface 15 which permits the user to select the amount of load W. The button 17 may comprise, for

example, two positions corresponding to the choice of a "full-load condition" or a "half-load condition" which may depend on the quantity of laundry loaded into the drum 9 by the user.

[0077] Alternatively, the full-load condition or the half-load condition may be decided on the base of the weight of the load detected and/or estimated by the central processing unit, as will be better described later. For example, as illustrated in Figure 4, if the weight of the detected load is less than 5kg then a "half-load condition" is set, while if the weight of the detected load is greater than 5kg then a "full-load condition" is set.

[0078] Once the amount of load W is determined (step 120), i.e. full-load condition or half-load condition, the proper drying cycle is chosen (step 130) according to the amount of load W previously determined (step 120).

[0079] The drying cycle is preferably defined, among other parameters, by the values of the rotation speed V of the compressor 24 during the drying process.

[0080] In a further preferred embodiment the drying cycle is preferably defined, among other parameters, by the values of the power P of compressor 24 during the drying process.

[0081] Other parameters which defines the drying cycle may be, for example, the drum rotation speed or the speed of the fan 12. In particular, the drum 9 is set rotating at favourable rotation speed. Furthermore, the rotational direction of the rotation is preferably changed at intervals in a reversing rhythm.

[0082] Figure 5 represents the course of the compressor speed V in a possible drying cycle which may be performed in a full-load condition, while Figure 6 represents the course of the compressor speed V in a possible drying cycle which may be performed in a half-load condition, according to the idea of the present invention. For the purpose of the present invention, by "course" it is meant a trend over the time.

[0083] In particular, if a full-load condition is determined then the compressor 24 is rotated at low speed V, for example 1900 rpm. On the contrary, if a half-load condition is determined then the compressor 24 is rotated at high speed V, for example 2300 rpm.

[0084] It is clear that the values of the compressor speed V above indicated, and all the values mentioned throughout the present description, are merely indicative and not limitative. They refer, in fact, to a particular type of compressor motor utilized. Compressors with different displacements (i.e. internal volume of the compression chamber) are driven at different speed rotation. Generally, the higher the displacement, the lower the rotation speed level required to achieve the same effect.

[0085] In the preferred drying cycles here illustrated, the compressor 24 rotates at a steady speed V for the entire drying cycle, i.e. up to time t<sub>4</sub>, apart from the beginning of the cycle where the compressor speed V increase from 0 to the desired steady speed V, as indicated in the time interval from t<sub>0</sub> to t<sub>0</sub>' in figures 5 and 6. In this interval, or acceleration phase, the compressor speed V for example increases linearly at 200rpm/sec.

[0086] According to the invention, the compressor speed V in half-load condition is higher than the compressor speed V in full-load condition.

[0087] Nevertheless, in different embodiments, the compressor speed V during the drying cycle may not be constant but varying over the time.

[0088] In this case, and more generally, we will refer to the average compressor speed V instead of the compressor speed V. It is clear that in case of a steady speed V, the compressor speed V and the average compressor speed V coincides.

[0089] In the present description, with "average compressor speed" it is meant the average value of the compressor speed over the interval of time in which the compressor is energized and operating, for example:

$$V = \frac{1}{t_4 - t_0} \int_{t_0}^{t_4} V(t) dt$$

[0090] With reference to the embodiment illustrated in figure 7, the compressor 24 is rotated at different speed V over the time t.

[0091] In Figure 7, both the full-load condition cycle and the half-load condition cycle of the compressor speed V over the time t are represented.

[0092] For example, the drying cycle may comprise an acceleration phase (from time t<sub>0</sub> to time t<sub>0</sub>'), a first phase (from time t<sub>0</sub>' to time t<sub>1</sub>) at a steady speed V, a second phase (from time t<sub>1</sub> to time t<sub>2</sub>) during which the speed V is decreased, a third phase (from time t<sub>2</sub> to time t<sub>3</sub>) during which the compressor is driven at a steady speed V lower than in the first phase and a final phase (from time t<sub>3</sub> to time t<sub>4</sub>) during which the speed V increases.

[0093] The choice of the times, in particular of t<sub>1</sub>, t<sub>2</sub>, t<sub>3</sub> and t<sub>4</sub>, are advantageously pre-determined and selected, for example, according to the type of product (cotton, wool, delicate, etc.) to be dried and are preferably selected by the user.

[0094] The first phase (t<sub>0</sub>'-t<sub>1</sub>) may then, preferably, last a long period of time, for example 20-30 min, during which the temperatures of the drying air stream A and of the heat pump system 20, which are usually at the ambient temperature when the laundry dryer 1 starts to operate, increase up to desired levels. This phase may also be called warm-up phase.

**[0095]** In the embodiment here illustrated, determination of the amount of load  $W$  is preferably carried out before the compressor is activated, i.e. before time  $t_0$ . Here, the choice of the proper drying cycle (step 130) according to the invention corresponds to a choice of one cycle between the full-load condition cycle and the half-load condition cycle of the compressor speed  $V$  over the time  $t$ . According to the invention, the compressor speed  $V_h$ , more particularly the average compressor speed  $V_h$ , in half-load condition is higher than the compressor speed  $V_f$ , more particularly the average compressor speed  $V_f$ , in full-load condition, as it results by comparing the two cycles in the graph of Figure 7. As illustrated, the function representing the full-load condition cycle substantially corresponds to function representing the half-load condition cycle shifted downwardly, i.e. towards lower values of speed  $V$ .

**[0096]** It is clear that any other drying cycle with different course may be advantageously performed, as described hereinafter.

**[0097]** For example in Figure 7A both the full-load condition cycle and the half-load condition cycle of the compressor speed  $V$  over the time  $t$  are represented, where the course of the two cycles are different.

**[0098]** In any case, the average compressor speed  $V_h$  in half-load condition is higher than the average compressor speed  $V_f$  in full-load condition. In this particular embodiment, the average compressor speed  $V_f$  is set lower than the average compressor speed  $V_f$  of the previous embodiment illustrated in figure 7.

**[0099]** Figure 7B shows a further embodiment of the invention.

**[0100]** Again, both the full-load condition cycle and the half-load condition cycle of the compressor speed  $V$  over the time  $t$  are represented, where the course of the two cycles are different.

**[0101]** In this embodiment, the compressor speed  $V$  in half-load condition and in full-load are the same during the acceleration phase ( $t_0$ - $t_0'$ ) and the first phase ( $t_0'$ - $t_1$ ).

**[0102]** In any case, the average compressor speed  $V_h$  in half-load condition is higher than the average compressor speed  $V_f''$  in full-load condition. In this particular embodiment, the average compressor speed  $V_f''$  is set higher than the average compressor speed  $V_f$  of the previous embodiment illustrated in figure 7. Furthermore, the determination of the amount of load  $W$  may still be preferably carried out before the compressor is activated, i.e. before time  $t_0$ .

**[0103]** Alternatively, the determination of the amount of load  $W$  may be preferably carried out during the acceleration phase ( $t_0$ - $t_0'$ ) or even better during the first phase ( $t_0'$ - $t_1$ ) of the drying cycle or, in other words, after the compressor 24 has been activated. In fact, as said before, the first phase (warm-up phase) may last a lot, for example 20min, so that the determination of the amount of load  $W$  may be carried out without wasting of time during this warm-up phase.

**[0104]** Figure 7C shows a further embodiment of the invention.

**[0105]** This embodiment differs from the previous embodiment illustrated in figure 7 for the different course of the cycle in full-load condition.

**[0106]** Again, the average compressor speed  $V_h$  in half-load condition is higher than the average compressor speed  $V_f'''$  in full-load condition. In this particular embodiment, the average compressor speed  $V_f'''$  is set lower than the average compressor speed  $V_f$  of the previous embodiment illustrated in figure 7.

**[0107]** Figure 7D shows a further embodiment of the invention.

**[0108]** This embodiment differs from the previous embodiment illustrated in figure 7 for the different course of the cycle in full-load condition.

**[0109]** In particular, the compressor speed  $V$  at some instants in full-load condition may be higher than the compressor speed  $V$  of the corresponding instants in half-load condition.

**[0110]** In any case, the average compressor speed  $V_h$  in half-load condition is higher than the average compressor speed  $V_f''''$  in full-load condition. In this particular embodiment, the average compressor speed  $V_f''''$  is set higher than the average compressor speed  $V_f$  of the previous embodiment illustrated in figure 7.

**[0111]** All the drying cycles above described may be advantageously pre-determined and selected, for example, according to the type of product (cotton, wool, delicate, etc.) to be dried and are preferably selected by the user.

**[0112]** The idea of the present invention is therefore to set the average rotation speed  $V$  of the compressor 24 according to the amount of load  $W$  of laundry to be dried.

**[0113]** As described above, if the load in the laundry drum 9 is set as a "half-load" by the user, then the upper average rotation speed  $V$  for the compressor 24 is activated. In contrast, if the load in the laundry drum 9 is set as a "full-load" by the user, then the lower average rotation speed  $V$  for the compressor 24 is activated.

**[0114]** Alternatively, if the load in the laundry drum 9 is lower than a predetermined threshold value (5kg), then the upper average rotation speed  $V$  for the compressor 24 is activated. In contrast, if the load in the laundry drum 9 is higher than the threshold value (5kg), then the lower average rotation speed  $V$  for the compressor 24 is activated. The threshold value advantageously correspond with the half of the maximum load in the laundry drum 9 (a threshold value of 5Kg for a maximum load of 10Kg).

**[0115]** Advantageously, according to the invention, if the amount of load  $W$  is low the average compressor speed  $V$  is high.

**[0116]** The idea of the invention derives from the fact that the amount of load  $W$  in the drum 9 affects the air flow stream inside the drum 9 itself.



**[0117]** The load, in fact, introduces a certain pressure drop in the air flow stream. This causes the air flow rate moved by the fan 12 to decrease. The higher the amount of load W is, the higher the pressure drop is. In turn, the higher the pressure drop is, the lower the air flow rate moved by the fan 12 is.

**[0118]** On the contrary, a low amount of load W causes a high flow rate moved by the fan 12.

**[0119]** The idea consists in driving the compressor 24 to adapt the working conditions of the heat pump system 20 to the air flow rate of said air flow stream.

**[0120]** As said above, in case of low amount of load W, the air flow rate is high: therefore the compressor 24 is driven at high speed level to exploit the high air flow.

**[0121]** The high air flow enhances the drying effect of the air stream on the laundry, thus reducing the drying cycle time required to dry the laundry.

**[0122]** In spite of the high compressor speed V and therefore its consumption, the total energy dissipated in the drying cycle is reduced due to the reduction of the drying cycle time itself.

**[0123]** The high compressor speed V, therefore, allows saving a substantial amount of energy and optimizes the removal of moisture from the laundry when the amount of load W is low.

**[0124]** In case of high amount of load W, the air flow rate is low: reducing the speed V of compressor 24 for reducing the refrigerant flow rate in the refrigerant circuit moved by the compressor itself allows matching the refrigerant flow rate to a lower air flow rate.

**[0125]** In fact, a high refrigerant flow rate combined to a low air flow rate level would be detrimental for the efficiency of the system. The heat pump system would work in disadvantageous working conditions and the compressor power adsorption would increase without speeding up the drying process. The high compressor speed V would be a source for inefficient energy consumption.

**[0126]** A low compressor speed, instead, advantageously does not reduce the drying efficiency and saves a substantial amount of energy.

**[0127]** It should be noted that air flow stream inside the drum 9 is moved by the fan 12, preferably rotated at a steady speed.

**[0128]** In different embodiment, nevertheless, the fan speed may be varied during the drying cycle according to a desired course over the time.

**[0129]** In the above described preferred embodiment, the compressor speed V is set according to two values of the load, i.e. half or full-load. The correlation between the compressor speed V and the amount of load W is therefore simple.

**[0130]** Figure 8 illustrates a schematic diagram of a second example of a correlation between the average compressor speed V and the amount of load W according to the present invention.

**[0131]** Here, the average compressor speed V is set at different values, actually five values, corresponding to five ranges for the amount of load W.

**[0132]** The following table shows such a correlation between the compressor speed V and the amount of load W, which corresponds with the diagram shown in Figure 8:

Amount of load W:	(Average) compressor speed V:
less than 2kg	2700 rpm
2-4 kg	2500 rpm
4-6 kg	2300 rpm
6-8 kg	2100 rpm
8-10 kg	1900 rpm

**[0133]** The optimal average compressor speed V is set according to the table above and/or the diagram of Figure 8. The correlation between the average compressor speed V and the amount of load W inside the laundry drum 9 is stored as a function or as a table in a memory of the control unit 26 and/or of the central processing unit. According to this function or table, every amount of load W in the laundry drum 9 is related to an ideal average speed V of the compressor 24.

**[0134]** In figure 9, the steady speed V of the compressor 24 during the drying cycle for the different amount of loads W is represented.

**[0135]** Here again, the rotation speed V of the compressor 24 is set according to the amount of load W being dried.

**[0136]** Here, the compressor speed V is set at different values, actually five values, corresponding to five ranges of amount of load W.

**[0137]** Therefore, more the amount of load W is and less the average compressor speed V is.

**[0138]** Also in this case, determining the amount of load W preferably includes detecting and/or estimating the amount of load W by evaluating predetermined working parameters of the laundry dryer, as will be better described later. Further,

determining the amount of load W in the laundry drum 9 includes receiving information about the amount of load W through a user selection of data. For example, the selection may include the provision of a selector 18 on the user control interface 15 which permits the user to select a desired range corresponding to the amount of load W. The selector 18 may comprise, for example, five positions corresponding to said ranges.

**[0139]** Nevertheless, in different embodiments, the compressor speed V during the drying cycle may not be constant but varying over the time.

**[0140]** As illustrated in Figure 10 the compressor 24 may therefore rotate at different speed V over the time t. In figure 10, the speed V of the compressor 24 during the drying cycle for the different amount of loads W is represented.

**[0141]** Here, the choice of the proper drying cycle (step 130) corresponds to a choice of one cycle between five different cycles over the time t.

**[0142]** In the above described preferred embodiments, determining of the amount of load W (step 120) preferably takes place at the beginning of the drying cycle. Preferably, this takes place during the first few minutes of the drying cycle, for example during the first five minutes, depending on the estimation criteria utilized.

**[0143]** More preferably, the step of determining of the amount of load W is carried out before the compressor 24 is activated.

**[0144]** The drying cycle then will continue according to the pre-determined course chosen.

**[0145]** Nevertheless, in further preferred embodiments, as already mentioned above, the step of determining of the amount of load W may be also carried out during any phase of the drying cycle, in particular during the warm-up phase.

**[0146]** The step of determining of the amount of load W is therefore carried out after the activation of the compressor 24.

**[0147]** While the method of the invention has been described only with reference to the control of the rotation speed V of the compressor 24, it is clear that the same applies if the power P of the compressor 24 is being controlled.

**[0148]** Such a situation is represented in Figure 11 where the power P of the compressor 24 is varied according to the amount of load W, instead of varying the compressor speed V as illustrated, for example, in Figure 8.

**[0149]** Hereinafter some possible criteria for detecting/estimating the amount of load W which may be advantageously performed in the method of the invention are described.

**[0150]** In a first preferred embodiment of the invention, the amount of load W in the laundry drum 9 may be directly detected by a weight sensor associated to the drum 9.

**[0151]** In another embodiment of the invention, the amount of load W may be determined by measuring the electrical parameters of the electric drum motor, like the electric current and/or the induced voltage. The electrical current through the electric drum motor is at least approximately proportional to the torque of the electric drum motor. For example, the electric current measured gives a measure of the torque of the electric drum motor and from the torque the amount of load W is determined.

**[0152]** In further embodiment, the torque of the electric drum motor may be detected and/or calculated differently, for example by means of a torque sensor associated to the drum motor.

**[0153]** The amount of load W in the laundry drum 9 may be further detected by the temperature difference of the air stream between an inlet and outlet of the laundry drum 9. The temperature difference of the inlet and outlet of the laundry drum 9 is related to the amount of water extracted from the laundry and decreases in the case of a small heat exchange between the air stream and the laundry.

**[0154]** Further, also the temperature of the air stream at the outlet of the laundry drum 9 can be used alone for estimating the amount of load W in the laundry drum 9.

**[0155]** In further embodiment, the amount of load W in the laundry drum 9 may be further detected by the temperature difference of the air stream between an inlet and outlet of the evaporator 23.

**[0156]** Moreover, the amount of load W may be estimated by measuring the electric resistance and/or conductivity of the wet laundry.

**[0157]** In this case, the amount of load W in the laundry drum 9 may be detected by using two electrodes associated to the laundry drum 9.

**[0158]** The electrodes are advantageously parts of a conductimetric system. Said conductimetric system may be provided for detecting both the dryness degree of the laundry inside the drum and for estimating the amount of load W in the laundry drum 9. For this purpose a level of electrical noise and/or fluctuation during the first minutes of a drying cycle is used. The wet load can connect electrically the first electrode to the second electrode, when a part of the wet load touches simultaneously the first electrode and the second electrode. If the wet load in the laundry drum 9 does not touch simultaneously the first electrode and the second electrode, then a peak is detected by the conductimetric system.

**[0159]** It has been found that there is a correlation between the number or frequency of peaks of the electric signal and the amount of load W in the laundry drum 9. The smaller the load inside the laundry drum 9 is, the higher the number or frequency of the detected peaks is, and the higher is an electrical noise measured by the conductimetric system.

**[0160]** Further, it has been found that the area subtended by peaks of an electric signal corresponding to the detected electric resistance and/or conductivity increases with a decreasing amount of load W in said laundry drum 9 and similarly the value of peaks of an electric signal corresponding to the detected electric resistance and/or conductivity increases

with a decreasing amount of load W in said laundry drum 9.

**[0161]** It has thus been shown that the present invention allows the set object to be achieved. In particular, it makes it possible to obtain a drying cycle which allow an additional saving of energy compared to machines of known type.

**[0162]** Although illustrative embodiments of the present invention have been described herein with reference to the accompanying drawings, it is to be understood that the present invention is not limited to those precise embodiments, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope or spirit of the invention. All such changes and modifications are intended to be included within the scope of the invention as defined by the appended claims.

## Claims

1. A method for controlling a laundry drying machine (1) of the type comprising a heat pump system (20) having a refrigerant circuit (30) for a refrigerant and comprising an air stream circuit (10) including at least one laundry drum (9) for receiving laundry to be dried, said refrigerant circuit (30) comprising:

- a compressor (24) with a variable rotation speed (V);
- a first heat exchanger (21) for a thermal coupling between said air stream circuit (10) and said refrigerant circuit (30) wherein the temperature of said air stream increases and the temperature of said refrigerant decreases; and
- a second heat exchanger (23) for a further thermal coupling between said air stream circuit (10) and said refrigerant circuit (30) wherein the temperature of said air stream decreases and the temperature of said refrigerant increases;

**characterized in that** said method comprises the steps of:

- determining the amount of load (W) in said laundry drum (9); and
- controlling the average speed (V) or the average power (P) of said compressor (24) in a drying cycle according to said amount of load (W), so that in case of a first amount of load (W) said average speed (V) or said average power (P) of said compressor (24) is set to a first operational value (V<sub>h</sub>) and in case of a second amount of load (W) said average speed (V) or said average power (P) of said compressor (24) is set to a second operational value (V<sub>f</sub>; V<sub>f'</sub>; V<sub>f''</sub>; V<sub>f'''</sub>; V<sub>f''''</sub>), wherein said first amount of load (W) is smaller than said second amount of load (W) and said first operational value (V<sub>h</sub>) is higher than said second operational value (V<sub>f</sub>; V<sub>f'</sub>; V<sub>f''</sub>; V<sub>f'''</sub>; V<sub>f''''</sub>).

2. The method according to claim 1, **characterized in that** said step of determining the amount of load (W) in said laundry drum (9) includes receiving information about the amount of load (W) through a user selection of data, said user selection of data preferably comprising the step acting on a button (17) or on a selector (18) of a user interface (15) of said laundry drying machine (1).

3. The method according to claim 1, **characterized in that** said step of determining the amount of load (W) in said laundry drum (9) includes detecting and/or estimating the amount of load (W) in said laundry drum (9), said step of detecting and/or estimating the amount of load (W) in said laundry drum (9) preferably comprising the step of evaluating working parameters of said laundry drying machine (1).

4. The method according to claim 3, **characterized in that** said step of evaluating working parameters of said laundry drying machine (1) comprises the step of detecting the weight of the load by means of a weight sensor associated to said laundry drum (9).

5. The method according to claim 3, **characterized in that** said step of evaluating working parameters of said laundry drying machine comprises the step of measuring the electrical and/or mechanical parameters of an electric drum motor, said step of measuring the electrical and/or mechanical parameters of an electric drum motor preferably comprising the step of measuring the electric current and/or the induced voltage and/or the torque of said electric drum.

6. The method according to claim 3, **characterized in that** said step of evaluating working parameters of said laundry drying machine comprises the step of detecting the temperature of the air stream at an inlet and/or at an outlet of said laundry drum (9) or detecting the temperature of the air stream at an inlet and/or at an outlet of said second heat exchanger (23).

7. The method according to claim 3, **characterized in that** said step of evaluating working parameters of said laundry drying machine comprises the step of detecting the electric resistance and/or conductivity of wet laundry by means of a conductometric system.

8. The method according to claim 7, **characterized in that** it comprises the step of estimating the amount of load (W) inside the laundry drum (9) by evaluating the noise and/or fluctuation of said detected electric resistance and/or conductivity.

9. The method according to claim 8, **characterized in that** said step of evaluating the noise and/or fluctuation of the detected electric resistance and/or conductivity comprises:

- measuring the value of peaks of an electric signal corresponding to the detected electric resistance and/or conductivity, and/or
- measuring the number of peaks within a time span of an electric signal corresponding to the detected electric resistance and/or conductivity, and/or
- measuring the area subtended by peaks of an electric signal corresponding to the detected electric resistance and/or conductivity.

10. The method according to claim 9, **characterized in that** said conductometric system comprises at least two electrodes suitable to contact said laundry inside said laundry drum (9).

11. The method according to any preceding claim, **characterized in that** said step of determining the amount of load (W) in said laundry drum (9) is carried out within a predetermined time interval at the beginning of the drying cycle.

12. The method according to any preceding claim, **characterized in that** said step of determining the amount of load (W) in said laundry drum (9) is carried out before the activation of said compressor (24).

13. The method according to any preceding claim from 1 to 11, **characterized in that** said step of determining the amount of load (W) in said laundry drum (9) is carried after the activation of said compressor (24).

14. The method according to any preceding claim, **characterized in that** said step of determining the amount of load (W) in said laundry drum (9) is carried out after said laundry drum (9) starts to rotate.

15. The method according to any preceding claim, **characterized in that** at least one predetermined threshold value for the amount of load (W) is defined, wherein above said threshold value said average speed (V) or said average power (P) of said compressor (24) is set to said second operational value ( $V_f$ ;  $V_f'$ ;  $V_f''$ ;  $V_f'''$ ;  $V_f''''$ ) and below said threshold value said average speed (V) or said average power (P) of said compressor (24) is set to said first operational value ( $V_h$ ).

16. The method according to any claim from 1 to 14, **characterized in that** two or more ranges for the amount of load (W) are defined and corresponding two or more operational values of said average speed (V) or of said average power (P) of said compressor (24) are set, wherein if the amount of load (W) is comprised in a first range which has smaller values than the values of a second range then the correspondent first operational value of said average speed (V) or of said average power of said compressor (24) is set at an operational value higher than the correspondent second operational value of said average speed (V) or of said average power of said compressor (24).

17. A laundry drying machine (1) suited to implement a method according to any of the preceding claims.

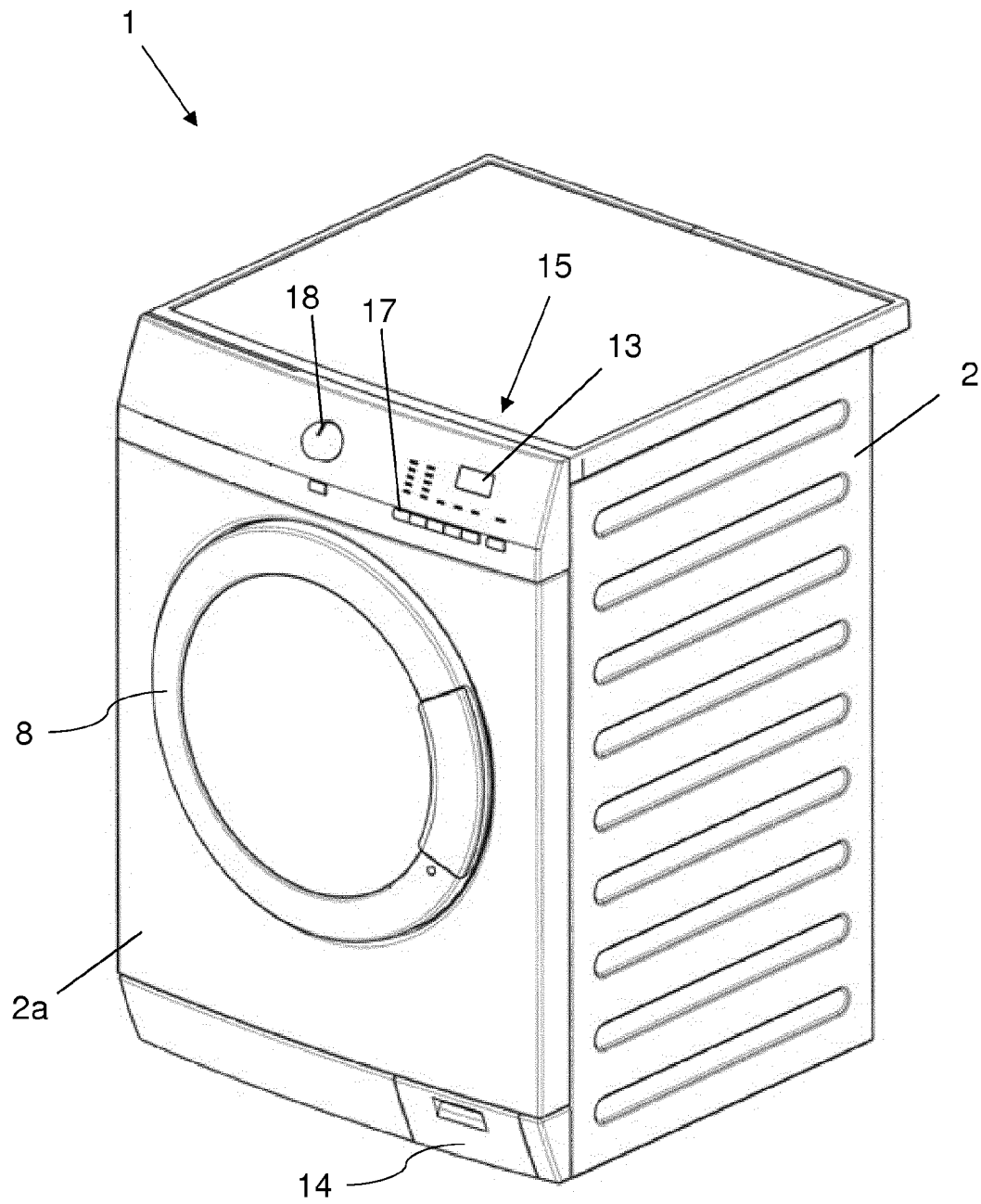


FIG. 1

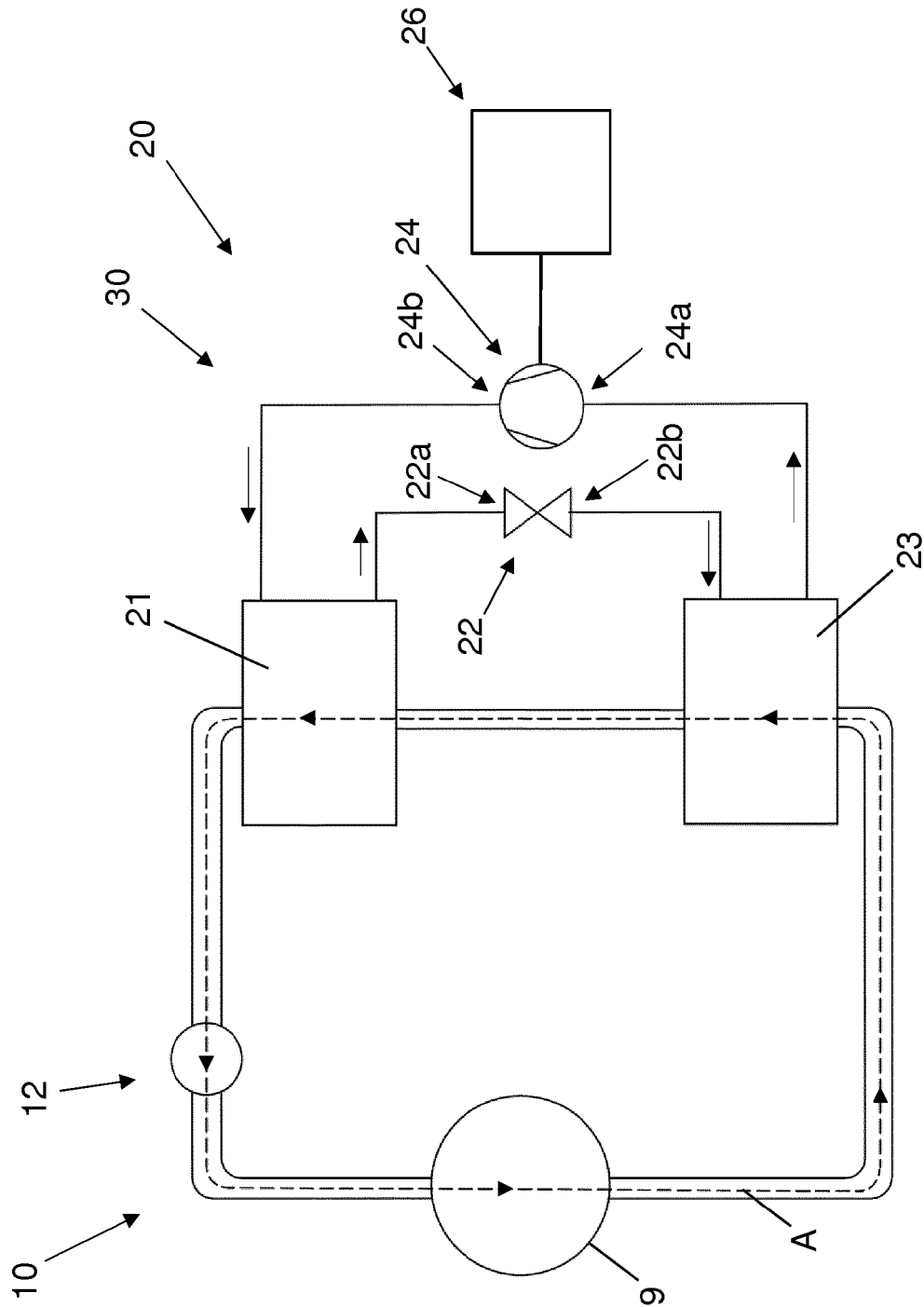


FIG. 2

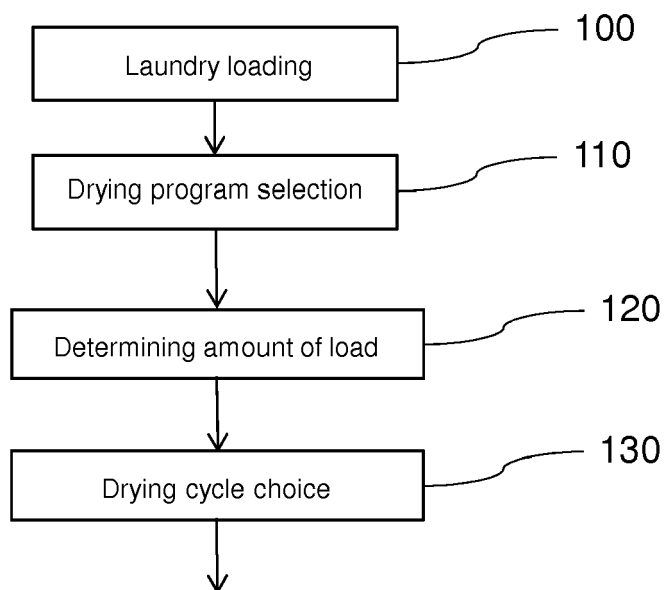


FIG. 3

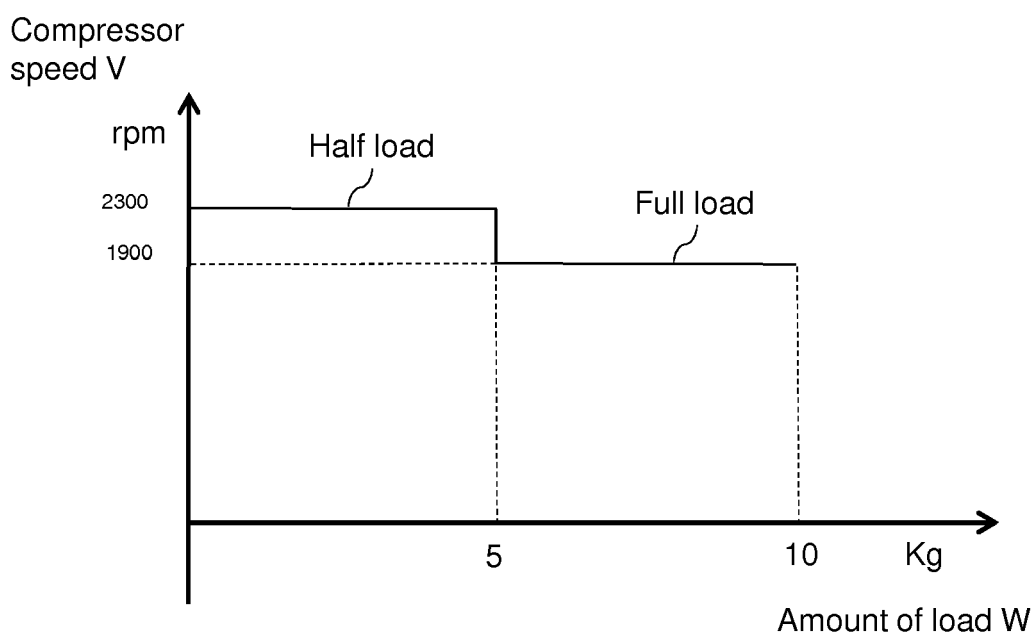


FIG. 4

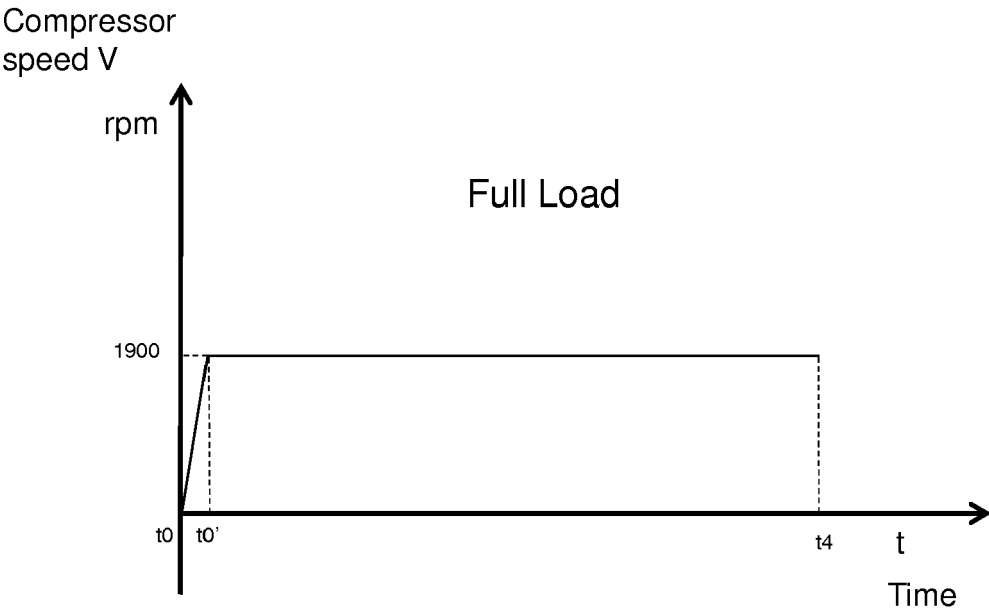


FIG. 5

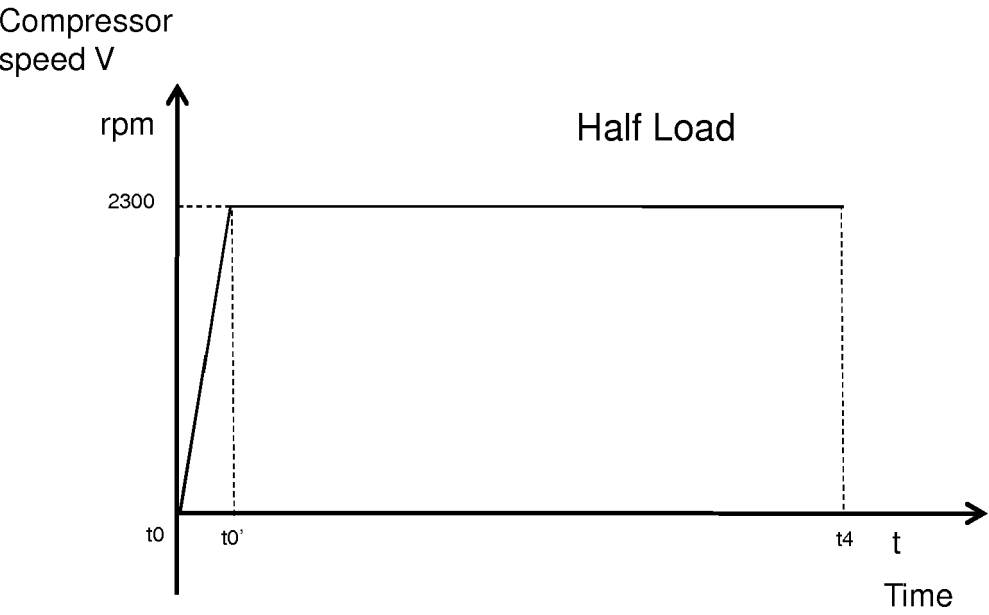


FIG. 6



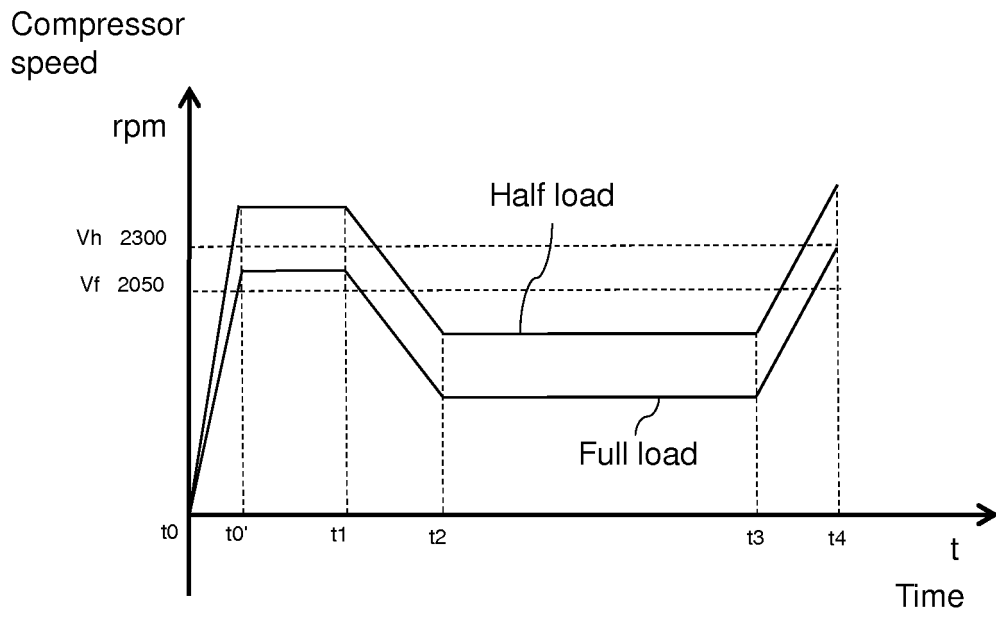


FIG. 7

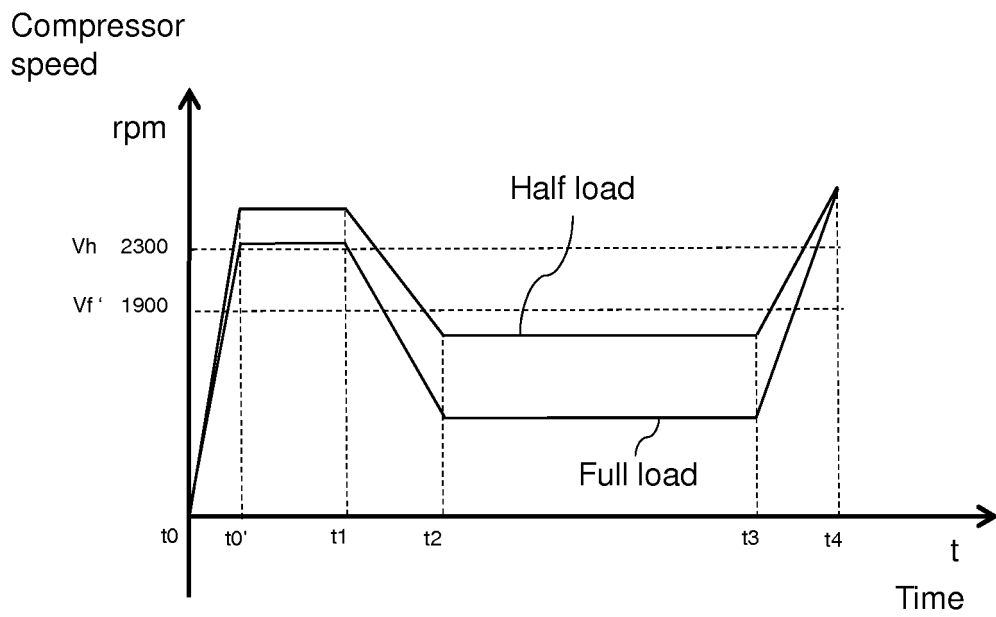
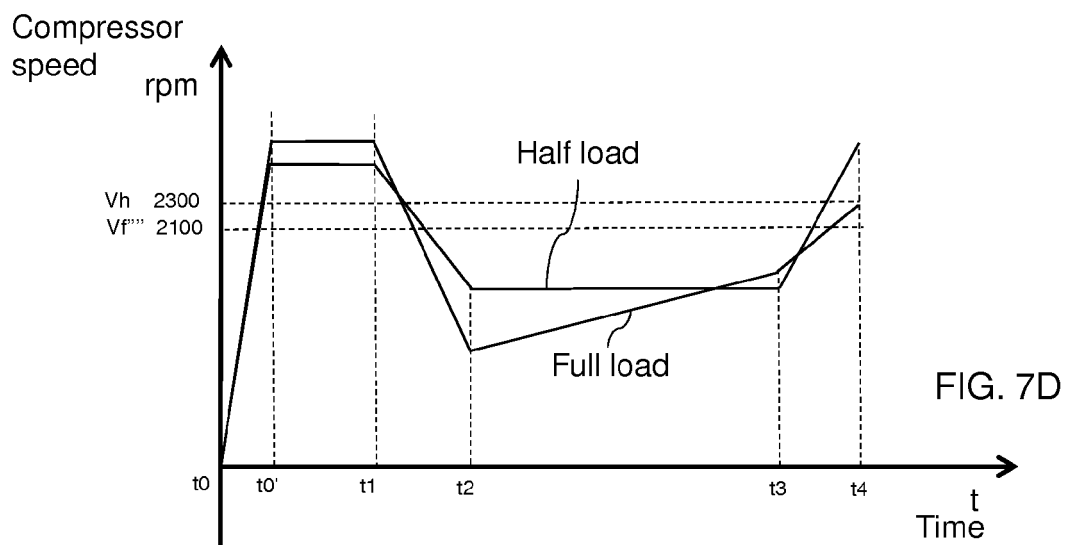
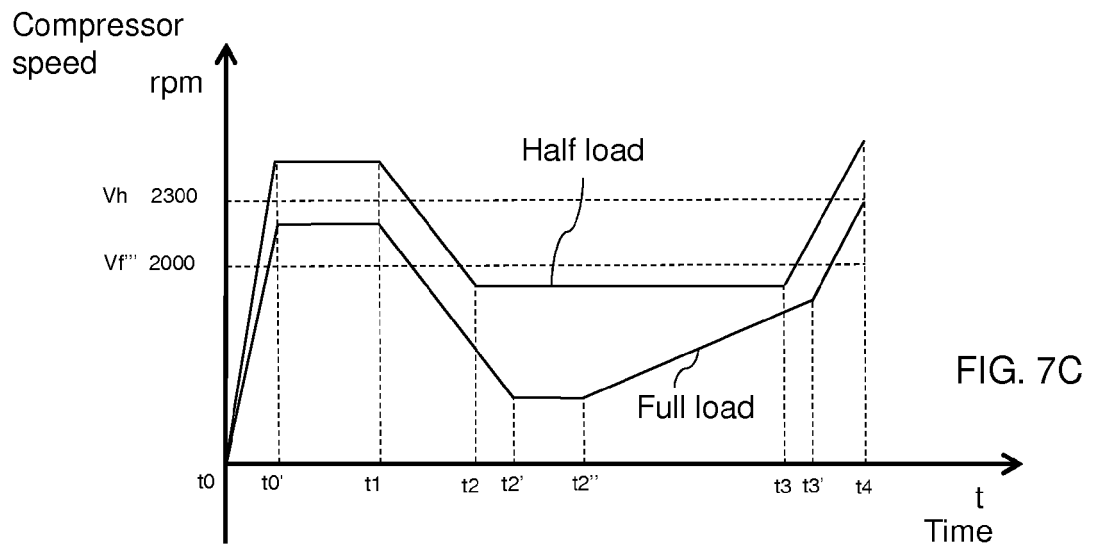
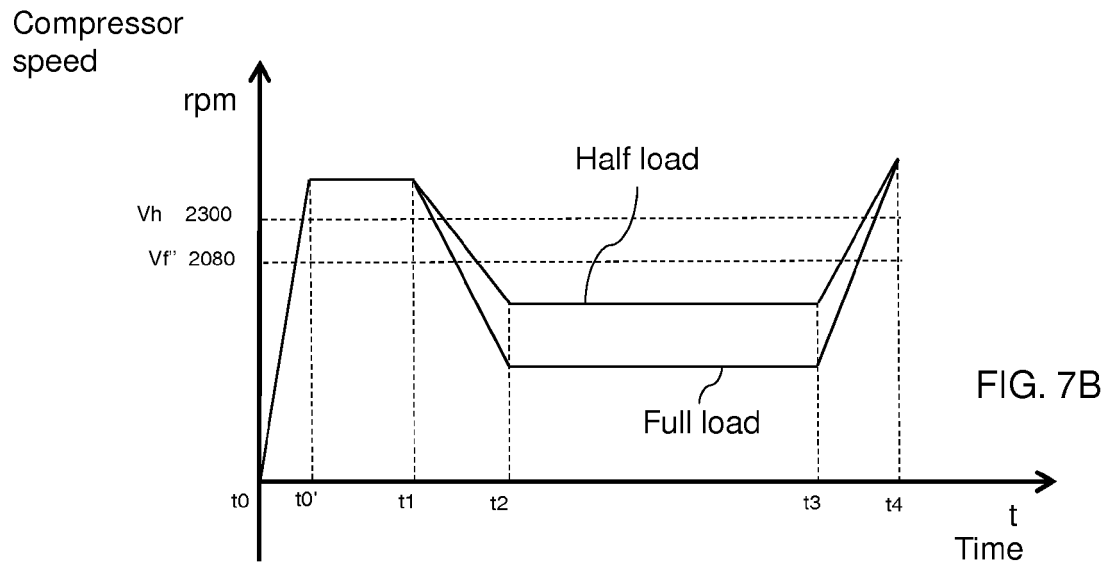
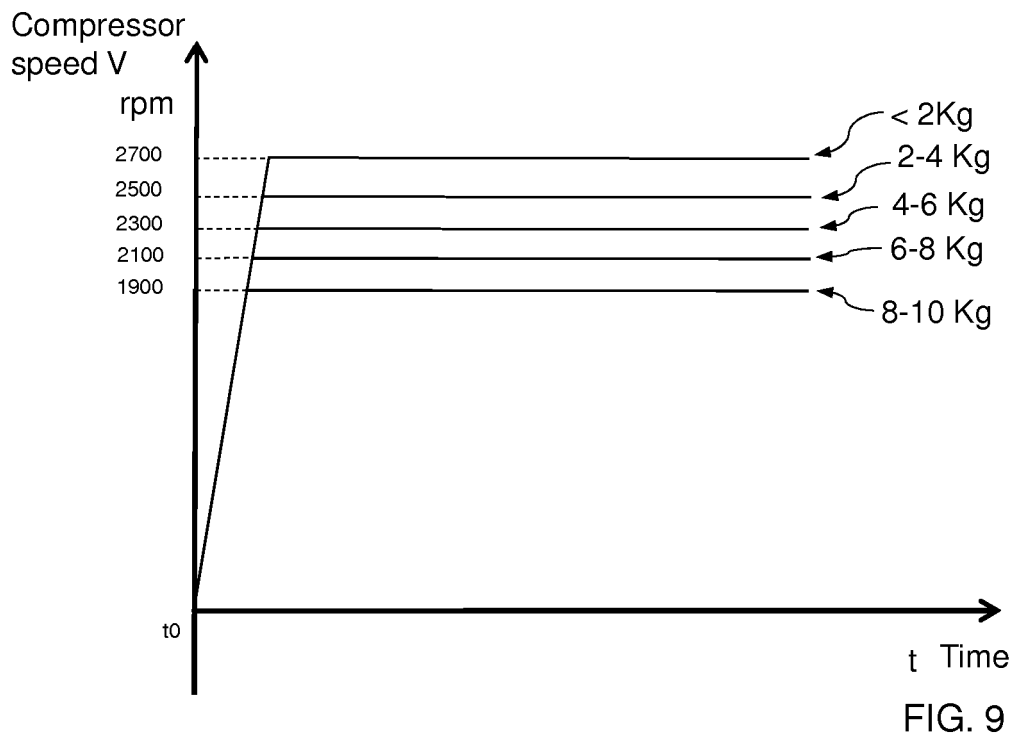
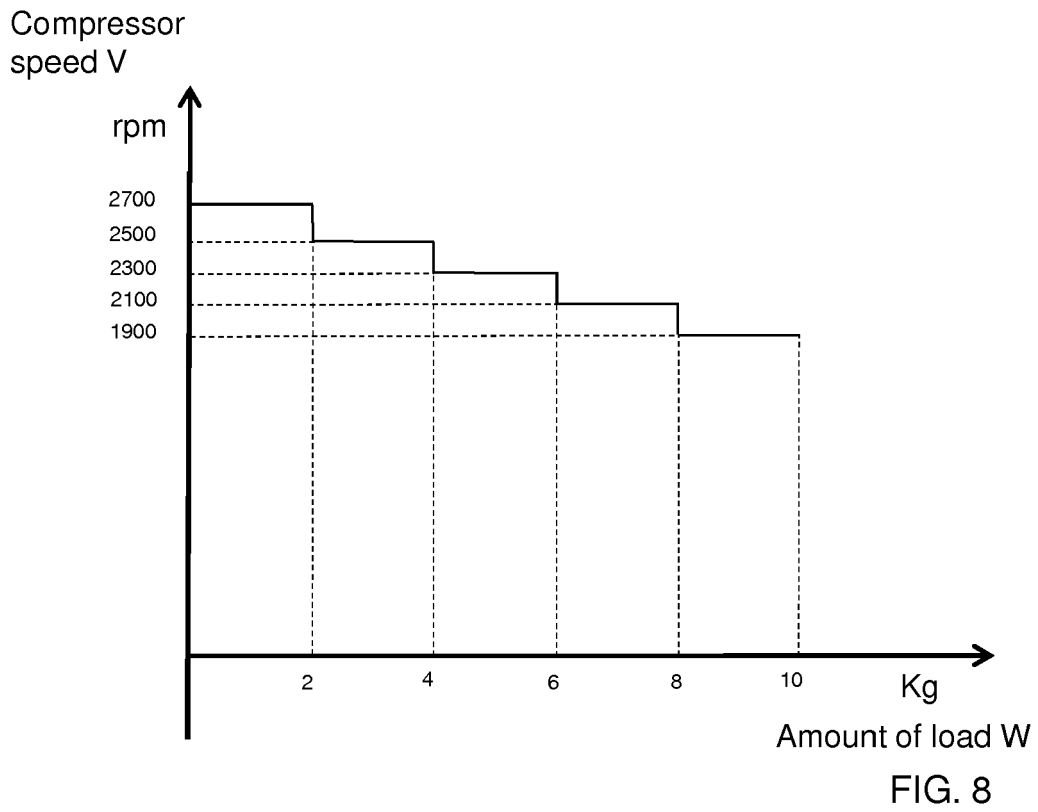


FIG. 7A





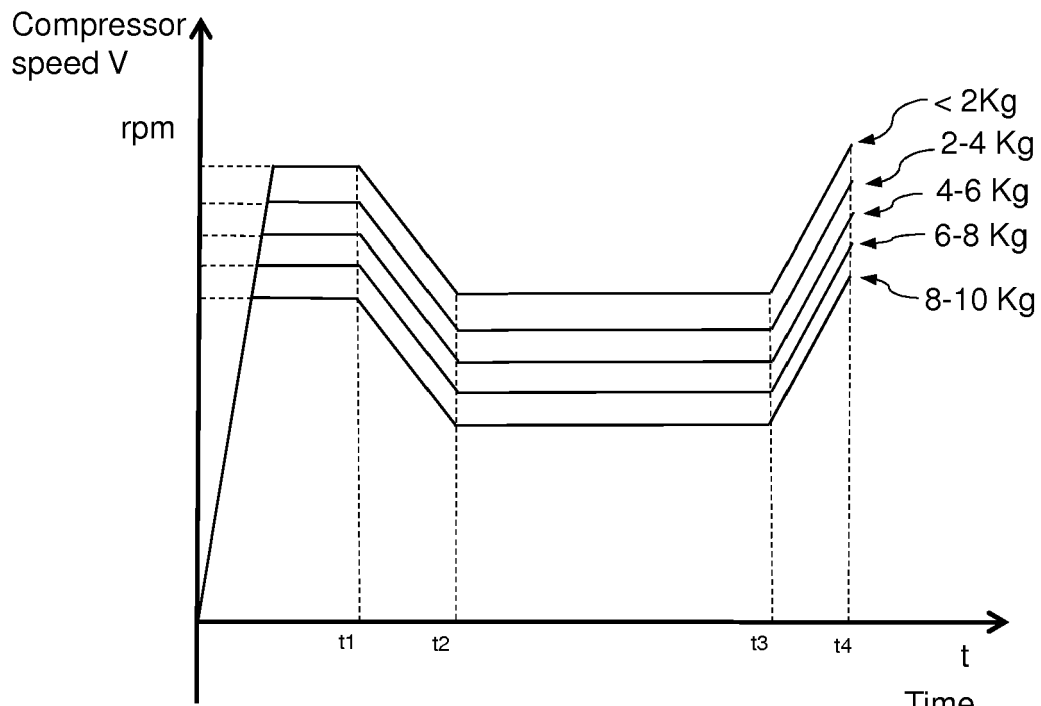


FIG. 10

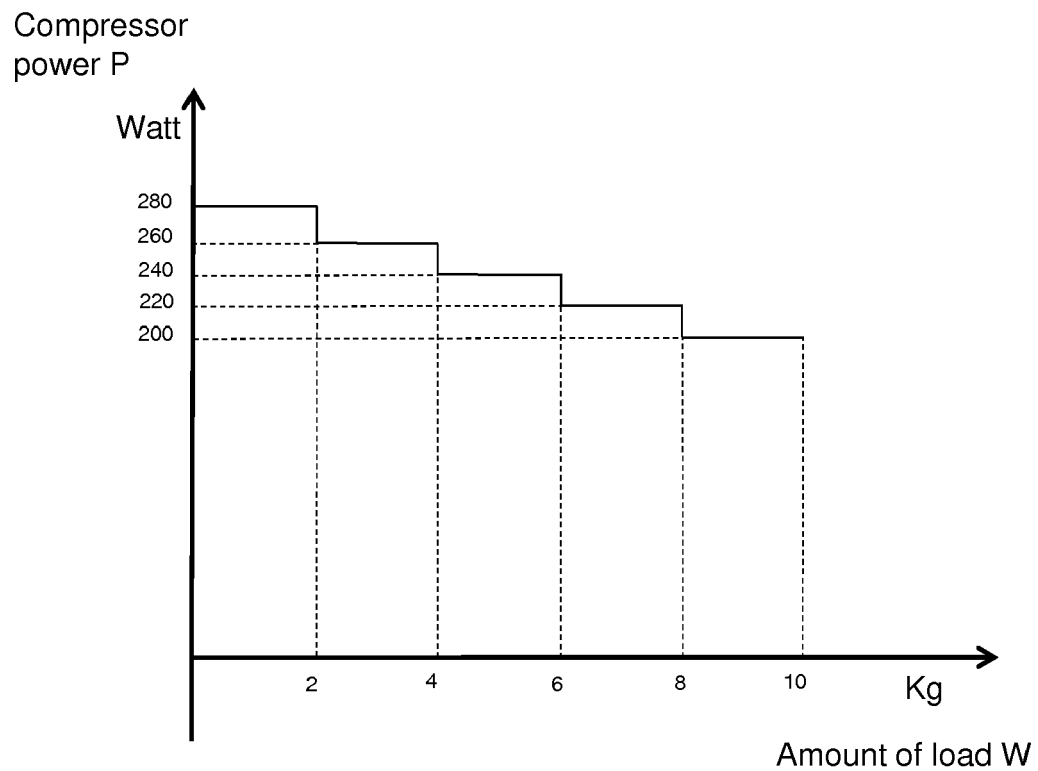


FIG. 11



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Y	* paragraphs [0007] - [0009] *	6-10	
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	* paragraphs [0031] - [0041] *		
	* paragraphs [0061], [0073] - [0079] *		
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	* paragraphs [0042] - [0058] *		
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Place of search Munich		Date of completion of the search 23 May 2013	Examiner Weinberg, Ekkehard
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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			

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