

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
9 July 2009 (09.07.2009)

PCT

(10) International Publication Number
WO 2009/083170 A2

(51) International Patent Classification:
D06F 58/20 (2006.01)

(21) International Application Number:
PCT/EP2008/010862

(22) International Filing Date:
18 December 2008 (18.12.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
07150493.0 31 December 2007 (31.12.2007) EP

(71) Applicant (for all designated States except US): **ELECTROLUX HOME PRODUCTS CORPORATION N.V.** [BE/BE]; Belgicastraat 17, B-1930 Zaventem (BE).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **BISON, Alberto** [IT/IT]; Via Damiani, 4/B, I-33170 Pordenone (IT). **DIANA, Emanuele** [IT/IT]; Via Puccini, 18, I-33080 Roveredo In Piano (IT). **DRIUSSI, Diego** [IT/IT]; Via

Trentino, 20/7, I-33080 Porcia (IT). **GIRO, Marino** [IT/IT]; Via Sassilas, 1, I-33080 Zoppola (IT).

(74) Agent: **NARDONI, Andrea**; Electrolux Italia S.P.A., Corso Lino Zanussi, 30, I-33080 Porcia (IT).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,

[Continued on next page]

(54) Title: ELECTRIC HOUSEHOLD APPLIANCE AND RELATIVE OPERATING METHOD

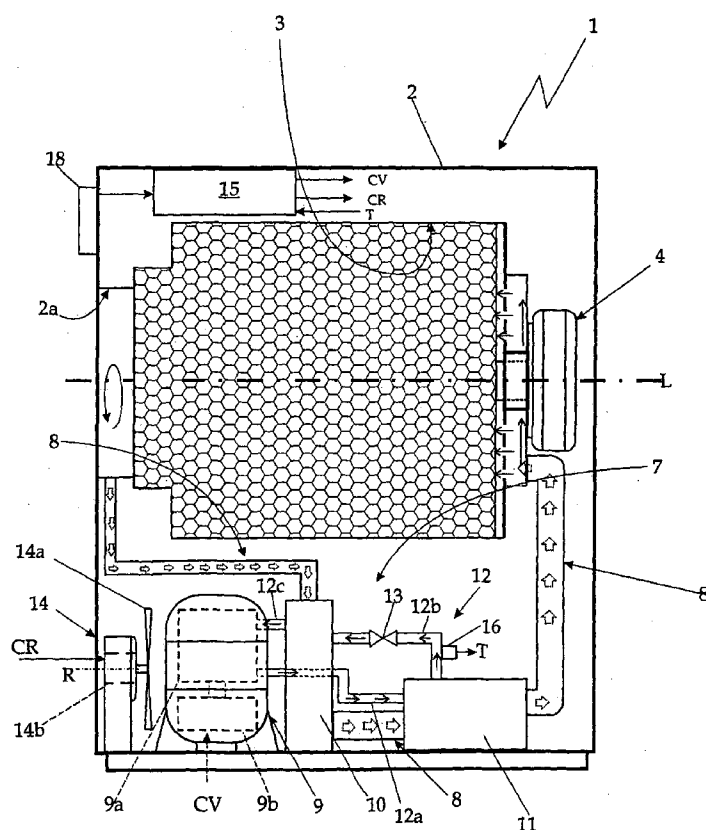


Fig. 1

(57) Abstract: An electric household appliance (1) having a hot-air generator (7) for feeding/drawing hot air to/from a drying drum (3) along an air-circulating pipe (8); a number of heat exchangers (10, 11) located along the air-circulating pipe (8) to allow a refrigerant to absorb/release heat from/to the airflow circulating in the air-circulating pipe (8); a compression device (9) having movable compression members (9a), and an electric motor (9b) for operating the movable compression members (9a); a fan (14a) for removing heat from the compression device (9); and an electronic central control unit (15), which controls the speed of the electric motor (9b) to achieve an intermediate speed (v_{int}) lower than a maximum speed (v_{MAX}) of the electric motor (9b), and activates/deactivates the fan (14a) to maintain the temperature (T) of the refrigerant within a predetermined range of a target temperature (T_0).



FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL,
NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG,
CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished
upon receipt of that report*

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ELECTRIC HOUSEHOLD APPLIANCE AND RELATIVE OPERATING
METHOD

10 The present invention relates to an electric household appliance and relative operating method.

More specifically, the present invention relates to a washer-drier machine employing a wash fluid comprising a silicone solvent and/or water, or to a tumble laundry
15 drier; to which the following description refers purely by way of example.

As is known, known home tumble laundry driers comprise: a substantially parallelepiped-shaped casing; a laundry drying drum mounted inside the casing to
20 rotate about an axis of rotation, and facing a laundry loading-unloading opening formed in the front wall of the casing; a door hinged to the front wall of the casing to rotate to and from a work position closing the opening in the front wall; and a drive assembly for
25 rotating the laundry drying drum about its axis of rotation.

Driers of the above type also comprise a hot-air generator for generating and circulating inside the

drying drum a stream of hot, low-moisture air which flows through the drying drum to rapidly dry the laundry inside.

More specifically, in some recently marketed
5 driers, the hot-air generator operates in the same way as a heat pump, circulates the same air inside the drying drum, and continually extracts the surplus moisture from the hot air issuing from the drying drum after flowing through the laundry inside the drum.

10 The hot-air generator comprises a refrigerant compression device or so-called compressor, which transfers heat from one fluid to another by means of an intermediate refrigerant subjected to a closed thermodynamic cycle, so as to rapidly cool and so reduce
15 the moisture content of the air issuing from the drying drum.

In driers of the above type, the compressor comprises a reciprocating or rotary mechanical compressor assembly to compress the intermediate gaseous
20 refrigerant; and an electric motor, the output shaft of which is connected to the mechanical compression member to rotate or produce reciprocating movement of the compression members.

More specifically, the electric motor is designed
25 to rotate its output shaft at constant speed, and to rotate or produce a reciprocating movement of the compression members to obtain a substantially constant average flow of compressed refrigerant, and is

controlled by the electronic central control unit via an on/off control system, which turns the electric motor on/off, depending on the balance condition of the intermediate refrigerant thermodynamic cycle.

5 More specifically, the blade rotation speed or linear piston speed of the compression members of the compressor can only assume two values: maximum, when the heat pump is working; or zero, when the heat pump is off.

10 As is known, at present, one of the major research goals in the drier market is that of devising straightforward, low-cost technical solutions by which to simultaneously reduce electric energy consumption and the noise level of the drier.

15 Accordingly, considerable effort has been made over the past few years to achieve relatively low overall electric energy consumption of the compressor, and, at the same time, to greatly reduce the noise level of the compression members of the compressor. A lot still
20 remains to be done, however.

It is therefore an object of the present invention to provide an electric household appliance, in particular a home laundry drier, which is highly efficient in terms of energy consumption, has a low
25 compressor noise level, and is particularly cheap to produce.

According to the present invention, there is provided an electric household appliance, in particular

a laundry drier, as claimed in Claim 1 and preferably, though not necessarily, in any one of the Claims depending directly or indirectly on Claim 1.

According to the present invention, there is also
5 provided a method of operating an electric household appliance, as claimed in Claim 6 and preferably, though not necessarily, in any one of the Claims depending directly or indirectly on Claim 6.

According to the present invention, there is also
10 provided an electronic control device for installation in an electric household appliance, and as claimed in Claim 9.

According to the present invention, there is also provided a software product as claimed in Claim 10.

15 A non-limiting embodiment of the present invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 shows a schematic lateral view of a tumble laundry drier in accordance with the teachings of the
20 present invention;

Figure 2 shows time graphs of the rotation speed of a compression device and refrigerant temperature in the course of an energy-saving drying cycle implemented by the Figure 1 drier.

25 Number 1 in Figure 1 indicates as a whole an electric household appliance, in particular a home laundry drier, substantially comprising a preferably, though not necessarily, parallelepiped-shaped casing 2;

and a laundry drying drum 3, which houses the laundry to be dried, is mounted to rotate freely inside casing 2 about a respective axis of rotation L, and directly faces a laundry loading-unloading opening 2a formed in the front wall of casing 2.

Drier 1 also comprises a drive assembly 4 for rotating laundry drying drum 3 about its axis of rotation L; and a door (not shown) hinged to the front wall of casing 2 to rotate to and from a work position closing opening 2a in the front wall to seal laundry drying drum 3.

Drier 1 also comprises a hot-air generator 7 housed inside casing 2 and designed to circulate inside drying drum 3 a stream of hot, low-moisture air, which flows over, to rapidly dry, the laundry inside the drum.

More specifically, hot-air generator 7 operates in the same way as a heat pump, by transferring heat from one fluid to another by means of an intermediate refrigerant subjected to a closed thermodynamic cycle, the thermodynamic principles of which are commonly known and therefore not described in detail, and provides for gradually drawing air from drying drum 3; extracting surplus moisture from the hot air drawn from drying drum 3; heating the dried air to a predetermined temperature, normally higher than that of the air inside drying drum 3; and feeding the heated, dried air back into drying drum 3, where it again flows over, to rapidly dry, the laundry inside the drum. In other words, hot-air

generator 7 continually dries and heats the air drawn from drying drum 3, to rapidly dry the laundry inside the drum.

In the schematic example shown in Figure 1, hot-air
5 generator 7 substantially comprises an air-circulating pipe 8 connected at one end to a perforated rear wall of drying drum 3 to feed hot air into drum 3, and at the other end to a front portion of drying drum 3, from which it draws moisture-laden air out of the drum.

10 Hot-air generator 7 also comprises a refrigerant compression device 9, or so-called compressor, which compresses the refrigerant (e.g. adiabatically) so that its pressure and temperature are much higher at the outlet than at the inlet of compression device 9.

15 More specifically, compression device 9 comprises a mechanical compression member 9a for compressing the refrigerant; and a variable-speed electric motor 9b, the output shaft of which is connected by a transmission (not shown) to mechanical compression member 9a to
20 transmit the rotary movement generated by electric motor 9b to mechanical compression member 9a.

More specifically, in one possible embodiment, compression device 9 may be a rotary compressor, in which mechanical compression member 9a comprises blades
25 rotating freely about an axis of rotation, and is connected to the output shaft of the electric motor, which rotates the blades to compress the gaseous refrigerant.

In another possible embodiment, compression device 9 may be a reciprocating compressor, in which mechanical compression member 9a comprises a piston mounted to slide freely, inside a compression chamber of compression device 9, between a suction position and a compression position; and a mechanical transmission device, which converts the rotary movement generated by the electric motor to linear movement of the piston. Reciprocating and rotary compression devices are known and therefore not described in detail, except to state that the variable-speed electric motor is preferably, though not necessarily, an inverter motor or brushless motor or any other similar electric motor.

With reference to Figure 1, hot-air generator 7 also comprises a first heat exchanger 10, or so-called evaporator, located along air-circulating pipe 8 and connected to compression device 9 so that the refrigerant absorbs heat from the airflow from drying drum 3, thus condensing the surplus moisture in the airflow.

Hot-air generator 7 also comprises a second heat exchanger 11, or so-called condenser, located along air-circulating pipe 8 and connected to compression device 9 to receive the refrigerant and so release heat to the airflow into drying drum 3.

Hot-air generator 7 also comprises a refrigerant circuit 12 for circulating refrigerant through compression device 9, first heat exchanger 10, and

second heat exchanger 11, to perform the heat-pump thermodynamic cycle.

More specifically, circuit 12 substantially comprises a first portion 12a connecting a heated-
5 refrigerant outlet of compression device 9 to an inlet of second heat exchanger 11; a second portion 12b connecting an outlet of second heat exchanger 11 to an inlet of first heat exchanger 10 via a laminar-flow valve 13; and a third portion 12c connecting an outlet
10 of first heat exchanger 10 to an inlet of compression device 9.

With reference to Figure 1, drier 1 also comprises a ventilation device 14 in turn comprising at least one fan 14a facing compression device 9 and rotating about a
15 respective axis R; and an electric motor 14b, which rotates fan 14a to remove heat from, and so cool, compression device 9.

Drier 1 also comprises an electronic central control unit 15, which regulates the speed of motor 9b
20 of compression device 9 by means of a signal CV, and turns electric motor 14b of ventilation device 14 on/off by means of a signal CR, so as to rotate fan 14a, or not, depending on the temperature T of the refrigerant circulating in refrigerant circuit 12.

25 Drier 1 also comprises at least one temperature sensor 16, e.g. a thermocouple, located along refrigerant circuit 12 to transmit to electronic central control unit 15 the temperature T of the refrigerant

circulating in refrigerant circuit 12. More specifically, in the Figure 1 example, temperature sensor 16 is located along second portion 12b of refrigerant circuit 12 to measure the temperature T of the refrigerant issuing from second heat exchanger 11.

Drier 1 also comprises an interface device 18 enabling the user to select an energy-saving drying cycle, which substantially provides for reducing, for a given time period, the rotation speed, with respect to a steady-operating rotation speed, of electric motor 9b of compression device 9, and for simultaneously activating/deactivating rotation of fan 14a to keep refrigerant temperature T around a predetermined target temperature T_0 .

The operating method of drier 1 will now be described, assuming the energy-saving drying cycle has been selected by the user on interface device 18.

With reference to Figure 2, when implemented by electronic central control unit 15, the energy-saving drying cycle comprises the following steps. To begin with, ventilation device 14 is kept off, and electronic central control unit 15 brings electric motor 9b of compression device 9 up to its maximum steady speed v_{MAX} (interval A in Figure 2).

The maximum steady speed v_{MAX} of electric motor 9b may be, for example, about 6000 rpm; and, at this step, the refrigerant temperature T measured along portion 12a of refrigerant circuit 12 increases rapidly (interval A

in Figure 2).

It should be point out that by applying such maximum steady speed v_{MAX} to the electric motor 9b, the dryer and the load to be dried therein are rapidly warmed up, having a short heating transitory phase thus advantageously speeding up the drying process.

After a predetermined interval ΔT of roughly 10-15 minutes from the start of the cycle, electronic central control unit 15 reduces the speed of motor 9b to an intermediate speed v_{int} lower than the maximum steady speed and ranging between roughly 1500-1800 rpm (interval B in Figure 2). At this step, temperature T increases at a much slower rate, on account of the reduction in speed v of electric motor 9b reducing compressed-refrigerant flow.

When the measured temperature T reaches a predetermined threshold T_{MAX} ranging between roughly 72-75°C, and preferably of 73°C, electronic central control unit 15 activates motor 14b of ventilation device 14 to rotate fan 14a, which begins removing heat from compression device 9 to reduce refrigerant temperature T (interval C in Figure 2).

At this point, electronic central control unit 15 maintains a substantially constant intermediate speed v_{int} of motor 9b of compression device 9.

When the measured temperature T is below a minimum temperature threshold T_{min} ranging, for example, between 65°C and 68°C, electronic central control unit 15

deactivates motor 14b and, therefore, fan 14a of ventilation device 14 (interval D in Figure 2), thus deactivating heat removal from compression device 9 by fan 14a, and so once more increasing refrigerant
5 temperature T (interval D in Figure 2). Temperature T is monitored constantly by electronic central control unit 15, which reactivates ventilation device 14 when the measured temperature T exceeds maximum threshold T_{MAX} (interval E in Figure 2).

10 Motor 14b of fan 14a is activated/deactivated repeatedly by electronic central control unit 15 when the temperature T measured by temperature sensor 16 exceeds/falls below maximum/minimum threshold T_{MAX}/T_{min} .

The advantages of the drier described above are
15 obvious : operating the electric motor of the compression device at a "low" intermediate speed with respect to the steady-operating speed provides for reducing both electric energy consumption and the noise level of the compression members. More specifically,
20 tests show a roughly 40% reduction in energy consumption of the drier, as compared with a known heat pump drier in the same operating conditions.

Clearly, changes may be made to electric household appliance 1 as described herein without, however,
25 departing from the scope of the present invention as defined in the accompanying Claims.

CLAIMS

1) An electric household appliance (1) comprising a laundry drum (3) for housing laundry for drying; an air-circulating pipe communicating with said laundry drum (3); hot-air generating means (7) for feeding/drawing hot air to/from said laundry drum (3) along said air-circulating pipe (8); heat-exchange means (10, 11) located along the air-circulating pipe (8) to allow a refrigerant to absorb/release heat from/to the airflow circulating in said air-circulating pipe (8); compression means (9) having movable compression members (9a) for compressing said refrigerant, and an electric motor (9b) for operating said movable compression members (9a); ventilation means (14) having at least one fan (14a) rotating about a respective axis of rotation (R) to remove heat from said compression means (9); and electronic control means (15) for controlling said electric motor (9b) to achieve a predetermined target temperature (T_o) of said refrigerant compressed by said movable compression members (9a); said drier being characterized in that said electronic control means (15) control the speed of said electric motor (9b) to achieve an intermediate speed (v_{int}) lower than a maximum steady speed (v_{MAX}) of the electric motor (9b); said electronic control means (15) also maintaining said intermediate speed (v_{int}) of said electric motor (9b) and alternately activating/deactivating said fan (14a) of said

ventilation means (14) to maintain the temperature (T) of said refrigerant within a predetermined range of said target temperature (T_o).

2) An electric household appliance as claimed in
5 Claim 1, wherein said electronic control means (15) measure the temperature (T) of said refrigerant, and activate said fan (14a) of said ventilation means (14) when the measured temperature (T) exceeds a predetermined maximum temperature threshold (T_{MAX}).

10 3) An electric household appliance as claimed in Claim 1 or 2, wherein said electronic control means (15) measure the temperature (T) of said refrigerant, and deactivate said fan (14a) of said ventilation means (14) when said measured temperature (T) is below a
15 predetermined minimum temperature threshold (T_{min}).

4) An electric household appliance as claimed in any one of the foregoing Claims, wherein said electric motor (9b) is a variable-speed electric motor.

5) An electric household appliance as claimed in
20 Claim 4, comprising interface means (18) enabling the user to select an energy-saving drying cycle, which provides for reducing, for a given time period, the rotation speed of said variable-speed electric motor (9b) of said compression means (9), and for
25 simultaneously activating/deactivating rotation of said fan (14a) to keep refrigerant temperature (T) around said predetermined target temperature (T_o).

6) A method of operating an electric household

appliance comprising a laundry drum (3) for housing laundry for drying; an air-circulating pipe communicating with said laundry drum (3); hot-air generating means (7) for feeding/drawing hot air to/from
5 said laundry drum (3) along said air-circulating pipe (8); heat-exchange means (10, 11) located along the air-circulating pipe (8) to allow a refrigerant to absorb/release heat from/to the airflow circulating in said air-circulating pipe (8); compression means (9)
10 having movable compression members (9a) for compressing said refrigerant, and an electric motor (9b) for operating said movable compression members (9a); ventilation means (14) having at least one fan (14a) rotating about a respective axis of rotation (R) to
15 remove heat from said compression means (9); and electronic control means (15) for controlling said electric motor (9b) to achieve a predetermined target temperature (T_0) of said refrigerant compressed by said movable compression members (9a); said method being
20 characterized by comprising the steps of:

- controlling the speed of said electric motor (9b) to achieve an intermediate speed (v_{int}) lower than a maximum steady speed (v_{MAX}) of the electric motor (9b);
- maintaining said intermediate speed (v_{int}) of said
25 electric motor (9b) and, at the same time, activating/deactivating said fan (14a) of said ventilation means (14) to maintain the temperature (T) of said refrigerant within a predetermined range of said

target temperature (T_0).

7) A method as claimed in Claim 6, and comprising the steps of : measuring the temperature (T) of said refrigerant, and activating said fan (14a) of said ventilation means (14) when the measured temperature (T) exceeds a predetermined maximum temperature threshold (T_{MAX}).

8) A method as claimed in Claim 6 or 7, and comprising the steps of : measuring the temperature (T) of said refrigerant, and deactivating said fan (14a) of said ventilation means (14) when said measured temperature (T) is below a predetermined minimum temperature threshold (T_{min}).

9) An electronic device (15) for controlling an electric household appliance (1), characterized by implementing a method as claimed in any one of Claims 6 to 8.

10) A software product loadable into the memory of electronic control means (15), and designed to implement, when executed, the method as claimed in any one of Claims 6 to 8.

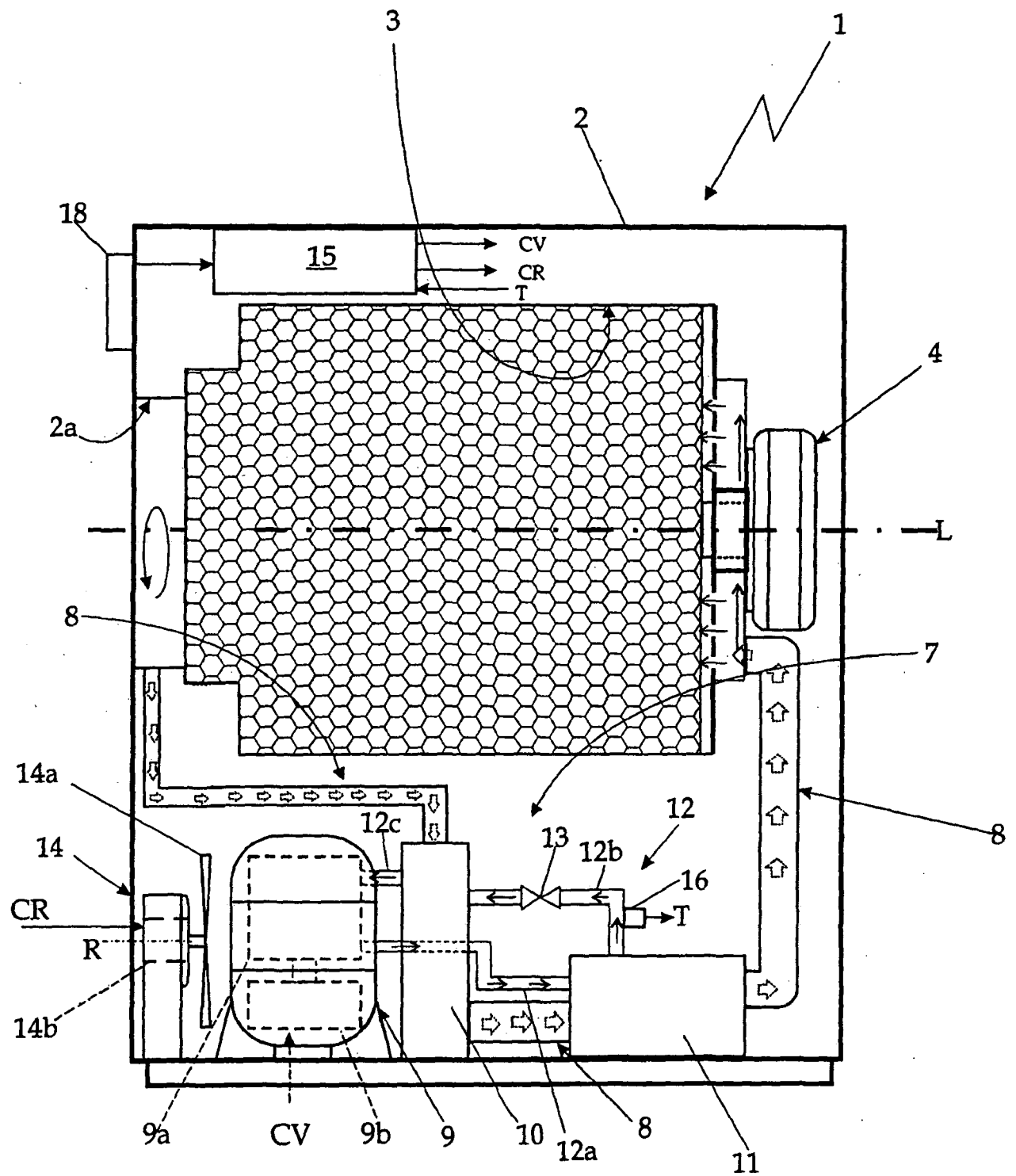


Fig. 1

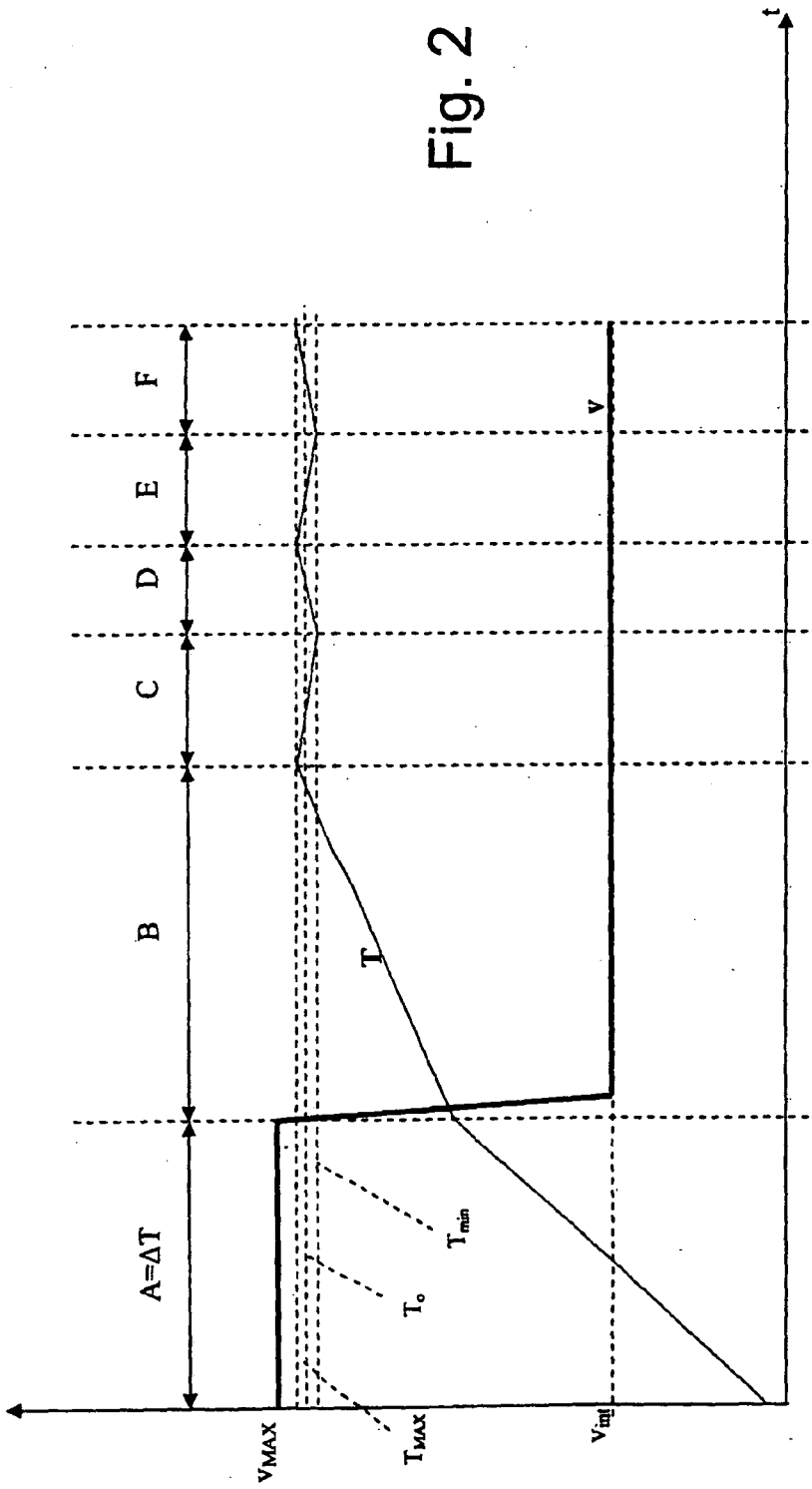


Fig. 2