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(54) Home laundry drier

(57) A home laundry drier (1) comprising an outer box casing (2) and, inside the casing, a laundry drying drum (3) for housing the laundry to be dried, and a hot-air generator (7) for circulating a stream of hot air inside the drying drum (3); the hot-air generator (7) comprising an air recirculating conduit (8) connected at both ends to the laundry drying drum (3), and a heat-pump assembly (10) which is able to rapidly cool the airflow (f) coming out from the drying drum (3) for condensing the surplus moisture in said airflow (f), and then to rapidly heat the airflow (f) returning back into the drying drum (3); the heat-pump assembly (10) using the carbon dioxide as refrigerant, and being designed to maintain the whole refrigerant in a gaseous state in all the thermodynamic transformations making up the closed thermodynamic cycle performed by the heat-pump assembly (10).

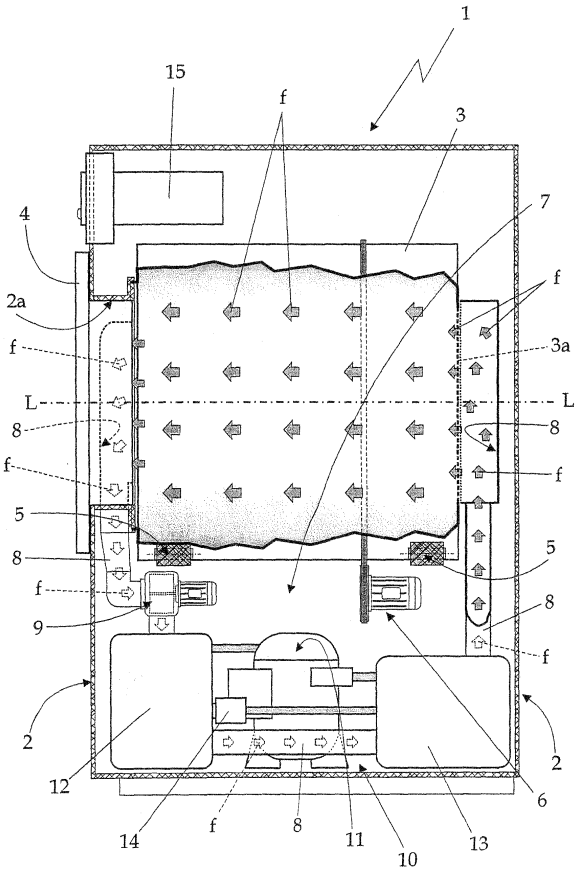

Fig. 1

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Description

[0001] The present invention relates to a home laundry drier.

[0002] More specifically, the present invention relates to a rotary-drum home laundry drier, to which the following description refers purely by way of example.

[0003] As is known, rotary-drum laundry driers comprise a substantially parallelepiped-shaped outer box casing; a cylindrical laundry drying drum housed in axially rotating manner inside the box casing, directly facing a laundry loading and unloading opening formed in the front face of the casing; a door hinged to the front face of the casing to rotate to and from a rest position closing the opening in the front face of the casing to seal the drying drum; and an electric motor for rotating the drying drum about its longitudinal axis inside the casing.

[0004] Rotary-drum laundry driers of the above type also comprise a closed-circuit, hot-air generator designed to circulate inside the drying drum a stream of hot air with a low moisture content, and which flows through the drying drum and over the laundry inside the drum to rapidly dry the laundry.

[0005] In some recently marketed driers, the closed-circuit, hot-air generator comprises an air recirculating conduit having its two ends connected to the drying drum, on opposite sides of the latter; an electric centrifugal fan or similar located along recirculating conduit to produce, inside the recirculating conduit, an airflow which flows through the drying drum; and finally a heat-pump assembly having its two heat exchangers located one after the other, along the air recirculating conduit. The first air/refrigerant heat exchanger of the heat-pump assembly provides for rapidly cooling the airflow arriving from the drying drum to condense the surplus moisture in the airflow; whereas the second air/refrigerant heat exchanger of the heat-pump assembly provides for rapidly heating the airflow arriving from the first heat exchanger and directed back to the drying drum, so that the airflow re-entering into the drying drum is heated rapidly to a temperature higher than or equal to that of the air flowing out of the drying drum.

[0006] More specifically, the heat-pump assembly of the hot-air generator generally comprises:

- a refrigerant compressing device which subjects a refrigerant in the gaseous state to compression, so that refrigerant pressure and temperature are much higher at the outlet than at the inlet of the compressing device;
- a first air/refrigerant heat exchanger, commonly referred to as the condenser, through which the refrigerant coming out from the compressing device and the airflow entering into the drying tub flow simultaneously, and which is designed so that the refrigerant releases heat to the airflow entering into the drying drum, while at the same time condensing in the liquid state;
- a second air/refrigerant heat exchanger, commonly referred to as the evaporator, through which the refrigerant flowing to the compressing device and the airflow coming out from the drying drum flow simultaneously, and which is designed so that the refrigerant absorbs heat from the airflow arriving from drying drum to cause condensation of the surplus moisture in the airflow, while at the same time completely turning back into the gaseous state; and
- a refrigerant expansion device which subjects the refrigerant flowing from the condenser to the evaporator to a rapid expansion, so that pressure and temperature of the refrigerant entering in the evaporator are much lower than pressure and temperature of the refrigerant coming out from the condenser, thus turning the refrigerant back into the gaseous state and completing the closed thermodynamic cycle in opposition to the compressing device, which provides for rapidly compressing the refrigerant.

[0007] Obviously, evaporator and condenser of the heat-pump assembly are located along the air recirculating conduit, so as that the evaporator provides for rapidly cooling the airflow arriving from the drying drum to condense the surplus moisture in the airflow, and the condenser provides for rapidly heating the airflow arriving from the evaporator and directed back to the drying drum, so that the airflow entering into the drying drum is heated rapidly to a temperature higher than or equal to that of the same air flowing out of the drying drum.

[0008] To improve heat exchange capabilities in the condenser of the heat-pump assembly for shortening the drying cycle of the laundry drier, US patent application US2005086827 envisages the use of the carbon dioxide as refrigerant in the heat-pump assembly, and also to keep the carbon dioxide in the gaseous state on the high pressure side of the heat-pump assembly.

[0009] In other words, the carbon dioxide has a supercritical pressure along the first heat exchanger of the heat-pump assembly, and turns into a two-phase state in the throttling valve located downstream of the first heat exchanger of the heat-pump assembly. The first heat exchanger, therefore, works as a normal gas cooler.

[0010] It is an object of the present invention to improve energy efficiency of the above cited closed-circuit, heat-pump-type, hot-air generator using carbon dioxide as refrigerant.

[0011] According to the present invention, there is provided a home 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.

[0012] 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 side view, with parts in section and parts removed for clarity, of a home laundry drier in accordance with the teachings of the present inven-

tion;

- Figures 2 is the temperature-entropy chart of the carbon dioxide disclosing a possible working curve of the closed thermodynamic cycle implemented by the heat-pump assembly of the Figure 1 home laundry drier.

[0013] With reference to Figure 1, number 1 indicates as a whole a home laundry drier comprising a preferably, though not necessarily, parallelepiped-shaped outer box casing 2; a preferably, though not necessarily, cylindrical bell-shaped laundry drying drum 3 for housing the laundry to be dried, and which is fixed in axially rotating manner inside casing 2, directly facing a laundry loading and unloading opening 2a formed in the front face of casing 2; and a door 4 hinged to the front face of casing 2 to rotate to and from a rest position closing opening 2a in the front face to seal laundry drum 3.

[0014] More specifically, in the example shown drying drum 3 rests horizontally inside casing 2 on a number of horizontal supporting rollers 5 which are fitted to casing 2 to let drying drum 3 freely rotate about its longitudinal axis L.

[0015] Casing 2, drying drum 3, door 4 and supporting rollers 5 are commonly known parts in the industry, and therefore not described in detail.

[0016] With reference to the attached drawing, laundry drier 1 also comprises a motor assembly 6 for rotating, on command, drying drum 3 about its longitudinal axis L inside casing 2; and a closed-circuit, hot-air generator 7 housed inside casing 2 and designed to circulate through drying drum 3 a stream of hot air having a low moisture level, and which flows over and rapidly dries the laundry inside drum 3.

[0017] More specifically, closed-circuit, hot-air generator 7 provides for gradually drawing air from drying drum 3; extracting surplus moisture from the hot air drawn from drying drum 3; heating the dehumidified air to a predetermined temperature, normally higher than the temperature of the air from drying drum 3; and feeding the heated, dehumidified air back into drying drum 3, where it flows over, to rapidly dry, the laundry inside the drum.

[0018] In other words, hot-air generator 7 provides for continually dehumidifying and heating the air circulating inside drying drum 3 to rapidly dry the laundry inside the drum, and substantially comprises:

an air recirculating conduit 8, the two ends of which are connected to drying drum 3 on opposite sides of the latter;

a centrifugal fan 9, or other type of air circulating pump, located along recirculating conduit 8 to produce, inside recirculating conduit 8, an airflow f which flows into drying drum 3 and over the laundry inside drum 5; and

a heat-pump assembly 10 which is able to rapidly cool the airflow f coming out from drying drum 3 for condensing the surplus moisture in the airflow f, and then to rapidly heat the airflow f returning back into drying drum 3, so that the airflow entering into drying drum 3 is heated rapidly to a temperature higher than or equal to that of the same air flowing out of the drying drum.

[0019] More specifically, in the example shown the intake end of recirculating conduit 8 is integrated in door 4, and is faced to the front opening of drying drum 3; the end wall 3a of drying drum 3 is perforated, or at any rate permeable to air, to permit air entry into drum 3; and the exhaust end of recirculating conduit 8 is coupled in airtight manner directly to the end wall 3a of drying drum 3.

[0020] As regards electric centrifugal fan 9, it is structured to produce an airflow f flowing, along recirculating conduit 8, from the intake end of recirculating conduit 8, i.e. door 4, to the exhaust end of recirculating conduit 8, i.e. perforated end wall 3a of drying drum 3.

[0021] With reference to Figure 1, heat-pump assembly 10 operates in the same way as a traditional heat-pump - which is capable of transferring heat from one fluid to another using an intermediate gaseous refrigerant subjected to a closed thermodynamic cycle, the thermodynamic principles of which are widely known and therefore not described in detail - and comprises:

a refrigerant compressing device 11 which subjects a gaseous refrigerant to compression (e.g. adiabatic compression) so that refrigerant pressure and temperature are much higher at the outlet than at the inlet of compressing device 11;

a first air/refrigerant heat exchanger 12 which is located along recirculating conduit 8 - preferably, thought not necessarily, downstream of centrifugal fan 9 - and is designed so that the airflow f from drying drum 3 and the refrigerant flowing to the inlet of compressing device 11 flow through it simultaneously, allowing the refrigerant having a temperature lower than that of the airflow f, to absorb heat from the airflow f thus causing condensation of the surplus moisture in the airflow f;

a second air/refrigerant heat exchanger 13 which is located along recirculating conduit 8, downstream of air/refrigerant heat exchanger 12, and is designed so that the airflow f directed to drying drum 3 and the refrigerant from the outlet of compressing device 11 flow through it simultaneously, allowing the refrigerant having a temperature greater than that of the airflow f to release heat to the airflow f, thus rapidly heating the airflow f to a temperature higher than of the airflow f coming out of the air/refrigerant heat exchanger 12, and preferably, thought not necessarily, also higher or equal to the temperature of the airflow f coming out of drying drum 3; and

a throttling valve or similar refrigerant expansion device 14 which subjects the refrigerant flowing from the second air/refrigerant heat exchanger 13 to the first air/refrigerant heat exchanger 12 to a rapid ex-

pansion, so that pressure and temperature of the refrigerant entering in air/refrigerant heat exchanger 12 are much lower than pressure and temperature of the refrigerant coming out from air/refrigerant heat exchanger 13, thus completing the closed thermodynamic cycle in opposition to the compressing device 11, which provides for rapidly compressing the refrigerant.

[0022] Likewise heat-pump assembly of traditional closed-circuit, heat-pump-type hot-air generators, refrigerant compressing device 11, first air/refrigerant heat exchanger 12, second air/refrigerant heat exchanger 13 and refrigerant expansion device 14 are connected one to the other via suitable connecting pipes, so as to form a closed circuit allowing the refrigerant coming out from the outlet of compressing device 11 to flow, in sequence, through air/refrigerant heat exchanger 13, refrigerant expansion device 14 and air/refrigerant heat exchanger 13, before returning to the inlet of compressing device 11.

[0023] Moreover, similarly to heat-pump assembly of the closed-circuit, heat-pump-type hot-air generator disclosed in US patent application US2005086827, heat-pump assembly 10 of drier 1 uses carbon dioxide as refrigerant but, differently from any other home laundry drier, heat-pump assembly 10 is designed to maintain the whole refrigerant, i.e. the carbon dioxide, in a gaseous state in all the thermodynamic transformations making up the closed thermodynamic cycle performed by the heat-pump assembly 10.

[0024] In other words, refrigerant compressing device 11, first air/refrigerant heat exchanger 12, second air/refrigerant heat exchanger 13 and refrigerant expansion device 14 are structured to prevent the carbon dioxide from undergoing a phase transformation (from a single-phase state to a two-phase state) along the whole closed circuit formed by refrigerant compressing device 11, first air/refrigerant heat exchanger 12, second air/refrigerant heat exchanger 13 and refrigerant expansion device 14.

[0025] More specifically, with reference to Figure 2, refrigerant compressing device 11, first air/refrigerant heat exchanger 12, second air/refrigerant heat exchanger 13 and refrigerant expansion device 14 are designed so as that all thermodynamic transformations making up the closed thermodynamic cycle performed by heat-pump assembly 10 - i.e. the refrigerant compression a-b, the refrigerant cooling b-c, the refrigerant rapid expansion c-d and the refrigerant heating d-a - remain above the saturation curve s of the carbon dioxide temperature-entropy chart.

[0026] In other words, the closed thermodynamic cycle performed by heat-pump assembly 10 is a totally supercritical closed thermodynamic cycle, and the carbon dioxide has a supercritical pressure both in the highpressure side (i.e. air/refrigerant heat exchanger 13) and in the low-pressure side (i.e. air/refrigerant heat exchanger 12) of the heat-pump assembly 10.

[0027] With reference to Figure 1, like any other recently marketed electric household appliance, home laundry drier 1 finally comprises an electronic central control unit 15 which controls electric motor assembly 6, centrifugal fan 9, and heat-pump assembly 10 - or, rather, compressing device 11 - in predetermined manner, as memorized inside it, to perform the user-selected drying cycle.

[0028] General operation of home laundry drier 1 is clearly inferable from the above description, with no further explanation required.

[0029] The use a heat-pump assembly performing a totally supercritical closed thermodynamic cycle with the carbon dioxide as refrigerant has lots of unexpected advantages. Laboratory tests, in fact, revealed that the profiles of gaseous carbon dioxide temperatures both in the highpressure side (i.e. air/refrigerant heat exchanger 13) and in the low-pressure side (i.e. air/refrigerant heat exchanger 12) of the heat-pump assembly 10 tailor perfectly to the air-temperature trends of the airflow f circulating in the two consecutive sections of recirculating conduit 8, thus significantly improving the exergetic efficiency of the heat transfer process.

[0030] This improvement of the exergetic efficiency leads to an unexpected outstanding improvement of the overall energy efficiency of the laundry drier, drastically reducing energy consumption.

[0031] In fact, being the same the amount of the heat exchanged, heat-pump assembly 10 operates with a higher value of the refrigerant pressure along the low pressure side of the heat-pump assembly 10, thus drastically reducing energy consumption of refrigerant compressing device 11.

[0032] Clearly, changes may be made to home laundry drier 1 as described herein without, however, departing from the scope of the present invention.

[0033] For example, home laundry drier 1 may be integrated in a laundry washing machine, thus obtaining a laundry washing/drying machine.

[0034] In which case, drying drum 3 is housed in axially rotating manner into an airtight, preferably, though not necessarily, cylindrical laundry drying tub or chamber, which is fixed substantially horizontally inside casing 2, directly facing the laundry loading and unloading opening 2a formed in the front face of casing 2; and door 4 is hinged to the front face of casing 2 for rotating to and from a rest position closing opening 2a in the front face to seal the laundry drying tub.

Claims

1. A home laundry drier (1) comprising an outer box casing (2) and, inside the casing, a laundry drying container (3) for housing the laundry to be dried, and a hot-air generator (7) for circulating a stream of hot air inside said laundry drying container (3); said hot-air generator (7) comprising an air recirculating conduit (8) connected at both ends to said laundry drying

container (3), and a heat-pump assembly (10) which is able to rapidly cool the airflow (f) coming out from the laundry drying container (3) for condensing the surplus moisture in said airflow (f), and then to rapidly heat the airflow (f) returning back into said laundry drying container (3); said home laundry drier (1) being **characterized in that** said heat-pump assembly (10) uses the carbon dioxide as refrigerant, and that said heat-pump assembly (10) is designed to maintain the whole refrigerant in a gaseous state in all the thermodynamic transformations making up the closed thermodynamic cycle performed by the heat-pump assembly (10).

2. A home laundry drier as claimed in Claim 1, **characterized in that** said heat-pump assembly (10) comprises a refrigerant compressing means (11) for compressing a refrigerant so that the pressure and temperature of the refrigerant at the outlet of the compressing means (11) are higher than the pressure and temperature of the refrigerant at the inlet of said compressing means (11); a first air/refrigerant heat exchanger (12) which is located along the recirculating conduit (8) and is designed so that the refrigerant flowing to the inlet of the refrigerant compressing means (11) and the airflow (f) from the laundry drying container (3) flow through it simultaneously, allowing the refrigerant to absorb heat from the airflow (f); a second air/refrigerant heat exchanger (13) which is located along recirculating conduit (8), downstream of said first air/refrigerant heat exchanger (12), and is designed so that the refrigerant from the outlet of the refrigerant compressing means (11) and the airflow (f) directed to the laundry drying container (3) flow through it simultaneously, allowing the refrigerant to release heat to the airflow (f); and a refrigerant expansion device (14) which subjects the refrigerant flowing from the second air/refrigerant heat exchanger (13) to the first air/refrigerant heat exchanger (12) to a rapid expansion, so that pressure and temperature of the refrigerant entering in the first air/refrigerant heat exchanger (12) are much lower than pressure and temperature of the refrigerant coming out from the second air/refrigerant heat exchanger (13).

3. A home laundry drier as claimed in Claim 1 or 2, **characterized in that** said hot-air generator (7) also comprises ventilating means (9) able to produce, along said recirculating conduit (8), an airflow (f) which flows through the laundry drying container (3).

4. A home laundry drier as claimed in Claim 3, **characterized in that** said first air/refrigerant heat exchanger (12) is located along the recirculating conduit (8), downstream of said ventilating means (9).

5. A home laundry drier as claimed in any of the forgoing Claims, **characterized in that** said laundry drying container (3) is a substantially cylindrical bell-shaped drum (3) fixed in axially rotating manner inside the outer box casing (2) of the drier.

6. A home laundry drier as claimed in Claim 5, **characterized in that** it also comprises driving means (6) for rotating, on command, said bell-shaped drum (3) about its longitudinal axis (L).

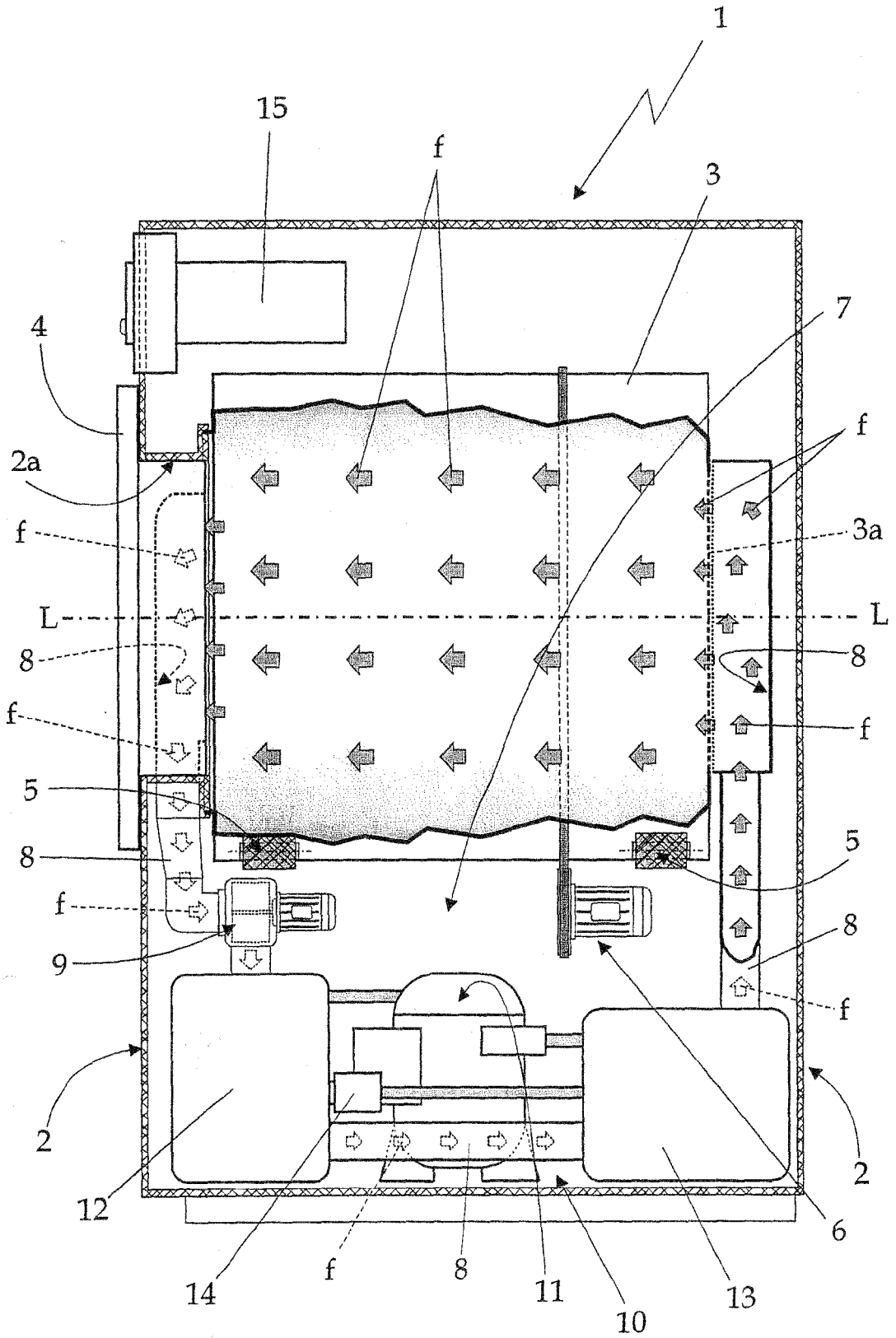
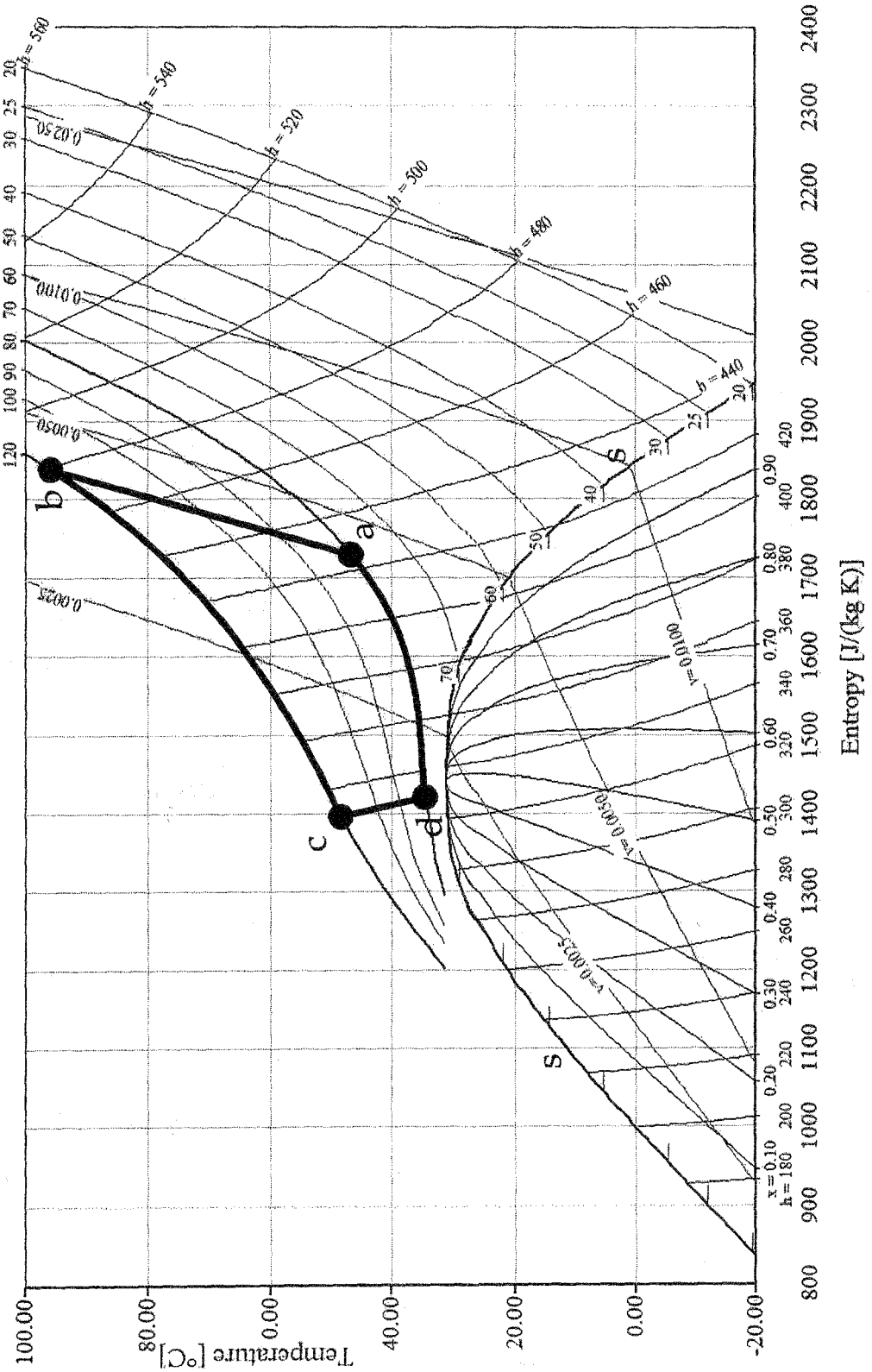


Fig. 1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Entropy [J/(kg K)]
a
b
c
d
s
h = 560
h = 540
h = 520
h = 500
h = 480
h = 460
h = 440
v = 0.0100
v = 0.0050
v = 0.0025
x = 0.10
h = 180

Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 07 12 1051

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
D,A	US 2005/086827 A1 (NAGAE ETSUSHI [JP] ET AL) 28 April 2005 (2005-04-28) * paragraph [0009] - paragraph [0011]; figure 1 *	1	INV. D06F58/20
A	US 2005/217133 A1 (YAKUMARU YUUICHI [JP] ET AL) 6 October 2005 (2005-10-06) * paragraph [0090] - paragraph [0093]; figures 1,5,10,11 *	1	
A	EP 1 632 736 A (SANYO ELECTRIC CO [JP]; SANYO ELECTRIC TECHNO CLEAN CO [JP]) 8 March 2006 (2006-03-08) * paragraph [0040]; figures 1,2 *	1	
A	WO 2005/075728 A (MATSUSHITA ELECTRIC IND CO LTD [JP]; YAKUMARU YUUICHI; TAMURA TOMOICHI) 18 August 2005 (2005-08-18) * page 9, line 35 - page 10, line 7; figures 1,8,13 *	1	
			TECHNICAL FIELDS SEARCHED (IPC)
			D06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	10 April 2008	Fachin, Fabiano

CATEGORY OF CITED DOCUMENTS

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10-04-2008

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005086827 A1	28-04-2005	CN 1590632 A	09-03-2005
		JP 3825772 B2	27-09-2006
		JP 2005083619 A	31-03-2005
US 2005217133 A1	06-10-2005	CN 1697953 A	16-11-2005
		EP 1614976 A1	11-01-2006
		WO 2004090431 A1	21-10-2004
EP 1632736 A	08-03-2006	CN 1746419 A	15-03-2006
		JP 2006078015 A	23-03-2006
		US 2006048404 A1	09-03-2006
WO 2005075728 A	18-08-2005	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 2005086827 A **[0008] [0023]**