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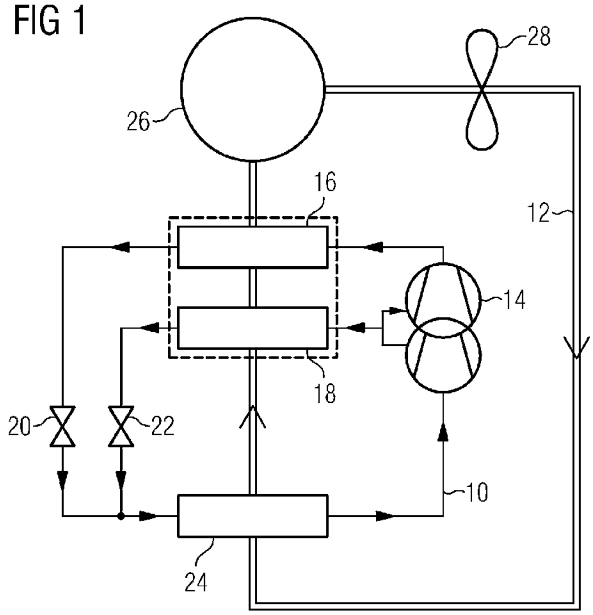
(54) A heat pump system for a laundry dryer

(57) The present invention relates to a heat pump system for a laundry dryer, said heat pump system comprises a refrigerant circuit (10) for a refrigerant and an air stream circuit (12) for an air stream. The refrigerant circuit (10) includes a compressor (14), a first heat exchanger (16), lamination means (20) and a second heat exchanger (24) connected in series and forming a loop. The air stream circuit (12) includes the first heat exchanger (16), a laundry drum (26), at least one air stream fan (26) and the second heat exchanger (24) connected in series and forming a closed loop. The refrigerant circuit (10) and the air stream circuit (12) are thermally coupled by the first heat exchanger (16) and the second heat exchanger (24). The compressor (14) is formed as a multi-stage compressor or as a plurality of serial compressors. The refrigerant circuit (10) includes at least one series of a third heat exchanger (18) and further lamination means (22). The compressor (14) includes an intermediate connection arranged between the stages of the multi-stage stage compressor or between the serial compressors, respectively. The intermediate connection of the compressor (14) is connected to the inlet of the third heat exchanger (18). The outlet of the further lamination means (22) is connected to the inlet of the second heat exchanger (24).

FIG 1



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Description

[0001] The present invention relates to a heat pump system for a laundry dryer according to the preamble of claim 1. Further, the present invention relates to a corresponding laundry dryer.

[0002] The heat pump technology is in a laundry dryer the most efficient way to dry clothes by reduced energy consumption. In a conventional heat pump laundry dryer an air stream flows in a close air stream circuit. For example, the air stream is moved by a fan, passes through a laundry drum, removes water from wet clothes, is then cooled down and dehumidified in an evaporator, heated up in a condenser and at last re-inserted into the laundry drum again. The refrigerant instead is compressed by a compressor, condensed in the condenser, laminated in an expansion device and then vaporized in the evaporator. Therefore the temperatures of the air stream and the refrigerant are strictly connected to each other.

[0003] The choice of the refrigerant becomes very important. On the one hand the performance of the heat pump system depends on the properties of the refrigerant. On the other hand the increasing awareness and sensitivity of the consumers for the problems related to the environment result in the desire for ecologically beneficial refrigerants. In particular, most currently used refrigerants contain HFCs.

[0004] Thus, natural fluids like carbon dioxide (CO_2) could play an important role in heat pump systems for laundry dryers. The heat pump systems using carbon dioxide as refrigerant differ from such heat pump systems, which use conventional fluids like R134a and R407C. Carbon dioxide has peculiar properties. The low critical temperature of carbon dioxide is about 31°C. The heating of the air stream up to about 60°C or 65°C forces the heat pump system working in a trans-critical cycle. Thus, in a high pressure portion of the refrigerant circuit the refrigerant is always kept in the gaseous phase. A gas cooler is provided for heating up the air stream and cooling down the refrigerant coming from the compressor. In contrast, in a traditional condenser the refrigerant condensates while the air stream is heated up. At the outlet of the gas cooler the density of the carbon dioxide increases, but there is no refrigerant in liquid state.

[0005] Usually, the compressors for carbon dioxide and further refrigerants are double stage compressors. FIG 2 shows a refrigerant circuit according to the prior art. The refrigerant circuit includes a compressor 14 formed as double stage compressor. Further, the refrigerant circuit includes a gas cooler 16, lamination means 18 and an evaporator 22. The double stage compressor 14 is characterized by having two inlets and two outlets, namely a low pressure suction, an intermediate pressure discharge, an intermediate pressure suction and a high pressure discharge. For usual heat pump applications, the intermediate pressure discharge and the intermediate pressure suction are welded together, so that the compressor behaves as one single stage compressor.

[0006] It is an object of the present invention to provide an improved heat pump system for a laundry dryer with low energy consumption.

[0007] The object of the present invention is achieved by the heat pump system according to claim 1.

[0008] According to the present invention

- the refrigerant circuit includes at least one series of a third heat exchanger and further lamination means,
- the compressor includes an intermediate connection arranged between the stages of the multi-stage compressor or between the serial compressors, respectively,
- the intermediate connection of the compressor is connected to the inlet of the third heat exchanger, and
- the outlet of the further lamination means is connected to the inlet of the second heat exchanger.

[0009] The present invention provides for dividing of the flow rate of the refrigerant at the outlet of compressor. One part of the refrigerant leaves the compressor at the intermediate connection of said compressor. The other part of the refrigerant leaves the compressor at the outlet of said compressor. Thus, the flow rates of the refrigerant are at two different pressure levels. The both flow rates of the refrigerant flow into different heat exchangers and release heat to the air stream. This results in a reduction of the power required by the compressor.

[0010] Preferably, the heat pump system comprises carbon dioxide as refrigerant.

[0011] Further, the refrigerant circuit and the air stream circuit are thermally coupled by the third heat exchanger.

[0012] In particular, the third heat exchanger is provided for heating up the air stream and cooling down the refrigerant.

[0013] In a compact heat pump system the first heat exchanger and the third heat exchanger may form a common heat exchanger with at least two different circuits for the refrigerant, wherein at least one circuit is provided for the first heat exchanger and at least one further circuit is provided for the third heat exchanger.

[0014] In particular, the refrigerant is provided for releasing heat to the air stream at different pressure levels.

[0015] Preferably, the first heat exchanger forms a high pressure gas cooler. In a similar way, the second heat exchanger forms an evaporator. Moreover, the third heat exchanger forms an intermediate pressure gas cooler.

[0016] The lamination means may be formed as a capillary tube and/or as an expansion valve (electronic or mechanical valve).

[0017] The electronic expansion valve is an on-off valve and/or the opening of the electronic expansion valve is continuously variable.

[0018] For example, the opening of the further lamination means depends on the pressure and/or the temperature of the refrigerant at the intermediate connection of the compressor.

[0019] Alternatively, the opening of the further lamination means depends on the temperature of the air stream at the outlet of the third heat exchanger or at the outlet of the first heat exchanger in the air stream circuit.

[0020] Instead of the electronic expansion valve or valves, respectively, a control valve may be provided at the intermediate connection of the compressor in order to control the flow rates of the refrigerant to the first heat exchanger and to the third heat exchanger.

[0021] Preferably, the heat pump system works at totally-supercritical conditions, wherein the refrigerant operates at least at the critical pressure through the first, second and third heat exchanger

[0022] The present invention relates further to a laundry dryer with at least one heat pump system, wherein the laundry dryer comprises at least one heat pump system mentioned above.

[0023] The novel and inventive features believed to be the characteristic of the present invention are set forth in the appended claims.

[0024] The invention will be described in further detail with reference to the drawings, in which

FIG 1 shows a schematic diagram of a heat pump system for a laundry dryer according to a preferred embodiment of the present invention, and

FIG 2 shows a schematic diagram of the heat pump system for the laundry dryer according to the prior art.

[0025] FIG 1 illustrates a schematic diagram of a heat pump system for a laundry dryer according to a first embodiment of the present invention. The heat pump system includes a closed refrigerant circuit 10 and a drying air circuit 12.

[0026] The refrigerant circuit 10 includes a compressor 14, a high pressure gas cooler 16, an intermediated pressure gas cooler 18, first lamination means 20, second lamination means 22 and an evaporator 24. The compressor 14 is formed as a multi-stage compressor and in a preferred embodiment the compressor is a double (two) stage compressor. As evident, multi-stage compressor includes a compressor having at least two stages of compression wherein the refrigerant compressed in a compression chamber passes into a further compression chamber for further compression. The following description will refer to a double stage compressor only for convenience.

[0027] The compressor 14 is formed as a double stage compressor. The double stage compressor 14 includes two single compressor stages connected in series. The inlet of the compressor 14 corresponds with the inlet of a first compressor stage. An intermediate connection of the compressor 14 corresponds with the outlet of the first compressor stage and the inlet of a second compressor stage. The outlet of the compressor 14 corresponds with the outlet of the second compressor stage.

[0028] The compressor 14, the high pressure gas cooler 16, the first lamination means 20 and the second evaporator 24 are switched in series and form a first loop of the refrigerant circuit 10. The first stage of the compressor 14, the intermediated pressure gas cooler 18, the second lamination means 22 and the evaporator 24 are switched in series and form a second loop of the refrigerant circuit 10. Thus, the intermediated pressure gas cooler 18 and the second lamination means 22 are arranged in parallel to the second stage of the compressor 14, the high pressure gas cooler 16 and the first lamination means 20. In other words, the outlet of the compressor 14 is connected to the inlet of the high pressure gas cooler 16, and the intermediate connection of the compressor 14 is connected to the inlet of the intermediated pressure gas cooler 18.

[0029] The drying air circuit 12 includes the evaporator 24, the intermediated pressure gas cooler 18, the high pressure gas cooler 16, a laundry treatment chamber 26, preferably a rotatable drum, and an air stream fan 28. The high pressure gas cooler 16, the intermediated pressure gas cooler 18 and the evaporator 24 are heat exchangers and form the thermal interconnections between the refrigerant circuit 10 and the drying air circuit 12. The evaporator 24 cools down and de-humidifies an during air, after said drying air has passed the laundry drum 26. Then, the intermediated pressure gas cooler 18 and the high pressure gas cooler 16 heat up the drying air, before the drying air is re-inserted into the laundry drum 26. The drying air stream is driven by the air stream fan 28.

[0030] The drying air is preferably circulated in a closed loop in which the drying air is preferably continuously flown through the laundry treatment chamber. However it may also be provided that a (preferably smaller) portion of the air stream is exhausted from the process air loop and fresh air (e.g. ambient air) is taken into the process air loop to replace the exhausted process air. And/or the process air loop is temporally opened (preferably only a small fraction of the total processing time) to have an open loop discharge

[0031] In any case, at least a part of the drying air after having passed through the evaporator 22 and gas heater 24 passes through the gas cooler 16.

[0032] The refrigerant circuit 10 is subdivided into a high pressure portion, a low pressure portion and an intermediate pressure portion. The high pressure portion extends from the outlet of the compressor 14 via the high pressure gas cooler 16 to the inlet of the first lamination means 20. The low pressure portion extends from the outlets of the lamination means 20 and 22 via the evaporator 24 to the inlet of the compressor 14. The intermediate pressure portion extends from the intermediate connection of the compressor 14 via the intermediated pressure gas cooler 18 to the inlet of the second lamination means 22.

[0033] The whole flow rate of the refrigerant is compressed and heated up by the first stage of the compressor 14. A certain part of the refrigerant leaves the compressor 14 via the intermediate connection of said compressor 14 and is cooled down in the intermediated pressure gas cooler 18 and laminated in the second lamination means 22. The other part of the refrigerant is further compressed and heated up by the second stage of the compressor 14, cooled down in the high pressure gas cooler 16 and laminated in the first lamination means 20. The two parts of the refrigerant are mixed before the inlet of the evaporator 24. Then, the whole flow rate of the refrigerant is vaporized by the evaporator 24 and sucked by the inlet of the compressor 14.

[0034] In this way, a part of the refrigerant is compressed from a low pressure level only to an intermediate pressure level. This results in a reduction of the power required by the compressor 14. This part of the refrigerant releases heat to the air stream in the intermediated pressure gas cooler 18. Then, the heating up of the air stream is completed by the high pressure gas cooler 16, where the temperature of the refrigerant is higher than in the intermediated pressure gas cooler 18.

[0035] The refrigerant works at three different pressure levels in the high pressure portion, the low pressure portion and the intermediate pressure portion, respectively.

[0036] The high pressure level occurs between the outlet of the compressor 14 and the inlet of the first lamination means 20. The intermediate pressure level occurs between the intermediate connection of the compressor 14 and the inlet of the second lamination means 22. The low pressure level occurs between the outlets of the lamination means 20 and 22 and the inlet of the compressor 14.

[0037] The temperature of the refrigerant in the high pressure gas cooler 16 is higher than the temperature of the refrigerant in the intermediated pressure gas cooler 18. Thus, it is preferred that the air stream coming from the evaporator 24 flows at first through the intermediated pressure gas cooler 18 and then through the high pressure gas cooler 16.

[0038] The high pressure gas cooler 16 and the intermediated pressure gas cooler 18 can be formed as two separate heat exchangers. Alternatively, one heat exchanger with two circuits for the refrigerant can be used. The one heat exchanger with two circuits is more compact.

[0039] The lamination means 20 and 22 can be realized by capillary tubes or by electronic valves. Preferably, the second lamination means 22 downstream the intermediated pressure gas cooler 18 is an electronic valve. In this way, the amount of the refrigerant flowing into the intermediated pressure gas cooler 18 can be modulated in dependence of the pressure and/or the temperature of the refrigerant at the intermediate connection of the compressor 14.

[0040] The electronic valve is completely closed until the pressure and/or the temperature of the refrigerant at the intermediate connection of the compressor 14 are higher than predetermined levels, so that the refrigerant is able to heat up the air stream in the air stream circuit 12. The electronic valve can be kept open at a fixed value, so that an on-off valve can be used. Alternatively, the opening of the electronic valve is modulated in dependence of the temperature of the air stream at the outlet of the intermediated pressure gas cooler 18 or at the outlet of the high pressure gas cooler 16 in the air stream circuit 12. The opening of the electronic valve is increasing until said temperature of the air stream starts decreasing. Then, the opening of the electronic valve is reduced.

[0041] The efficiency of the heat pump system increases with the amount of the refrigerant flowing into the intermediated pressure gas cooler 18. However, a minimum amount of the refrigerant must flow into the high pressure gas cooler 16 in order to heat up the air stream up to a desired level. The refrigerant in the high pressure gas cooler 16 is at a higher temperature level than the refrigerant in the intermediated pressure gas cooler 18.

[0042] Additionally or alternatively to the electronic valve, a control valve can be provided at the intermediate connection of the compressor 14 in order to modulate the flow rates of the refrigerant to the intermediated pressure gas cooler 18 and to the high pressure gas cooler 16. Said control valve may be actuated in dependence of the pressure and/or the temperature of the refrigerant and/or the temperature of the air stream in the air stream circuit 12 in order to assure a proper flow rate of the refrigerant through the high pressure gas cooler 16.

[0043] According to an alternative embodiment of the present invention a plurality of separate compressors (two in preferred embodiment) arranged in series may be used instead the multi-stage compressor 14. The separate compressors work at different pressure levels, wherein the outlet of the compressor running at the lower pressure is connected to the inlet of the compressor running at the higher pressure.

[0044] FIG 2 shows a schematic diagram of the heat pump system for the laundry dryer according to the prior art. Same or comparable components of the heat pump system have the same reference numerals as in FIG 1. The refrigerant circuit includes a compressor 14, a gas cooler 16, lamination means 18 and an evaporator 22.

[0045] The compressor 14 is formed as double stage compressor. The double stage compressor 14 is characterized by having two inlets and two outlets, namely a low pressure suction, an intermediate pressure discharge, an intermediate pressure suction and a high pressure discharge. For usual heat pump applications, the intermediate pressure discharge and the intermediate pressure suction are welded together, so that the compressor behaves as one single stage compressor.

[0046] Although an illustrative embodiment of the present invention has been described herein with reference to the accompanying drawings, it is to be understood that the present invention is not limited to that precise embodiment, 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.

List of reference numerals

[0047]

10 refrigerant circuit

12 air stream circuit

14 compressor

16 high pressure gas cooler, first heat exchanger

18 intermediate pressure gas cooler, third heat exchanger

20 first lamination means

22 second lamination means

24 evaporator, second heat exchanger

26 laundry drum

28 air stream fan

Claims

1. A heat pump system for a laundry dryer, said heat pump system comprises a refrigerant circuit (10) for a refrigerant and an air stream circuit (12) for an air stream, wherein

- the refrigerant circuit (10) includes a compressor (14), a first heat exchanger (16), lamination means (20) and a second heat exchanger (24) connected in series and forming a loop,
- the air stream circuit (12) includes the first heat exchanger (16), a laundry treatment chamber (26), at least one air stream fan (26) and the second heat exchanger (24),
- the refrigerant circuit (10) and the air stream circuit (12) are thermally coupled by the first heat exchanger (16) and the second heat exchanger (24),
- the first heat exchanger (16) is provided for heating up the air stream and cooling down the refrigerant,
- the second heat exchanger (24) is provided for cooling down the air stream and heating up the refrigerant, and
- the compressor (14) is formed as a multi-stage compressor or a plurality of serial compressors,

characterized in, that

- the refrigerant circuit (10) includes at least one series of a third heat exchanger (18) and further lamination means (22),
- the compressor (14) includes an intermediate connection arranged between the stages of the multi-stage compressor or between the serial compressors, respectively,
- the intermediate connection of the compressor (14) is connected to the inlet of the third heat exchanger (18), and
- the outlet of the further lamination means (22) is connected to the inlet of the second heat exchanger (24).

2. The heat pump system according to claim 1, **characterized in, that** the heat pump system comprises carbon dioxide as refrigerant.

3. The heat pump system according to claim 1 or 2, **characterized in, that** the refrigerant circuit (10) and the air stream circuit (12) are thermally coupled by the third heat exchanger (18).

4. The heat pump system according to any one of the preceding claims, **characterized in, that** the third heat exchanger (18) is provided for heating up the air stream and cooling down the refrigerant

5. The heat pump system according to any one of the preceding claims, **characterized in, that** the first heat exchanger (16) and the third heat exchanger (18) form a common heat exchanger with at least two different circuits for the refrigerant, wherein at least one circuit is provided for the first heat exchanger (16) and at least one further circuit is provided for the third heat exchanger (18).

6. The heat pump system according to any one of the preceding claims, **characterized in, that** the refrigerant is provided for releasing heat to the air stream at different pressure levels.

7. The heat pump system according to any one of the preceding claims, **characterized in, that** the first heat exchanger (16) forms a high pressure gas cooler.

8. The heat pump system according to any one of the preceding claims, **characterized in, that** the second heat exchanger (24) forms an evaporator.

9. The heat pump system according to any one of the preceding claims,
characterized in, that
the third heat exchanger (18) forms an intermediate pressure gas cooler.

10. The heat pump system according to any one of the preceding claims,
characterized in, that
the lamination means (20, 22) are formed as a capillary tube and/or as an electronic expansion valve and/or a mechanical valve.

11. The heat pump system according to claim 10, **characterized in, that**
the electronic expansion valve (20, 22) is an on-off valve and/or the opening of the electronic expansion valve (20, 22) is continuously variable.

12. The heat pump system according to claim 11, **characterized in, that**
the opening of the further lamination means (22) depends on the pressure and/or the temperature of the refrigerant at the intermediate connection of the compressor (14).

13. The heat pump system according to claim 11, **characterized in, that**
the opening of the further lamination means (22) depends on the temperature of the air stream at the outlet of the third heat exchanger (18) or at the outlet of the first heat exchanger (16) in the air stream circuit (12).

14. The heat pump system according to any one of the claims 1 to 10,
characterized in, that
a control valve is provided at the intermediate connection of the compressor (14) in order to control the flow rates of the refrigerant to the first heat exchanger (16) and to the third heat exchanger (18).

15. A laundry dryer with at least one heat pump system,
characterized in, that
the laundry dryer comprises at least one heat pump system according to any one of the claims 1 to 14.

FIG 1

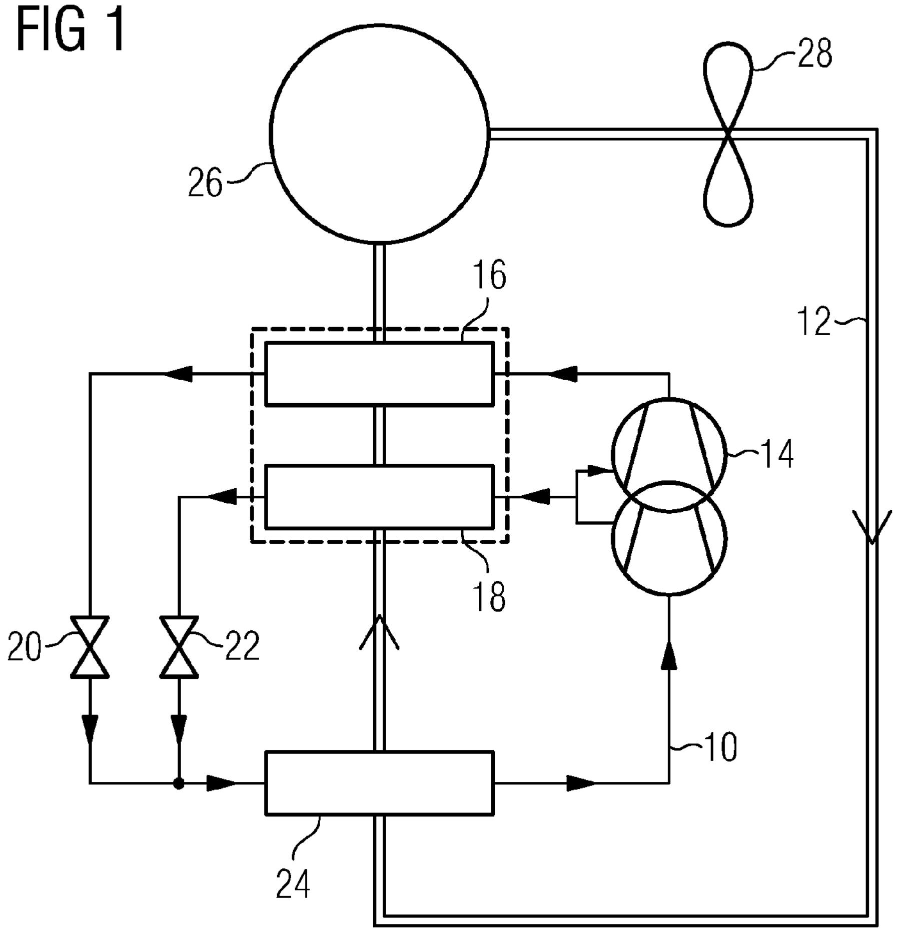
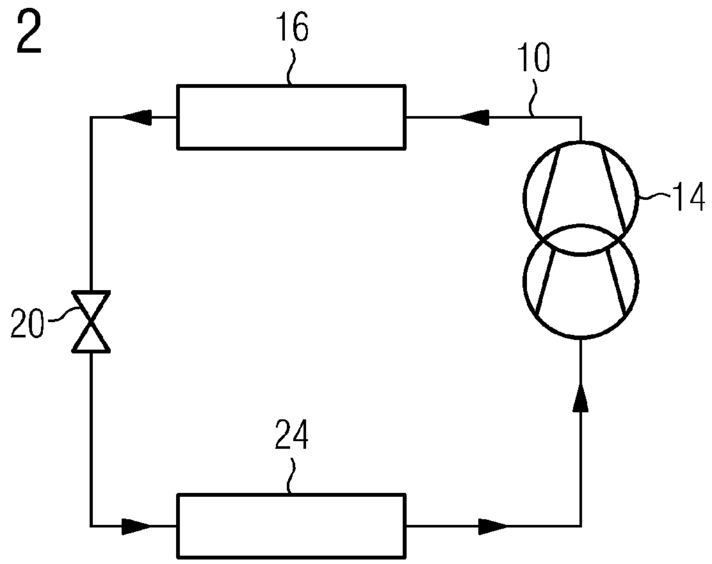


FIG 2



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EUROPEAN SEARCH REPORT

Application Number
EP 11 17 5739

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	EP 2 060 671 A1 (ELECTROLUX HOME PROD CORP [BE]) 20 May 2009 (2009-05-20) * the whole document *	1-15	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 January 2012	Spitzer, Bettina

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CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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