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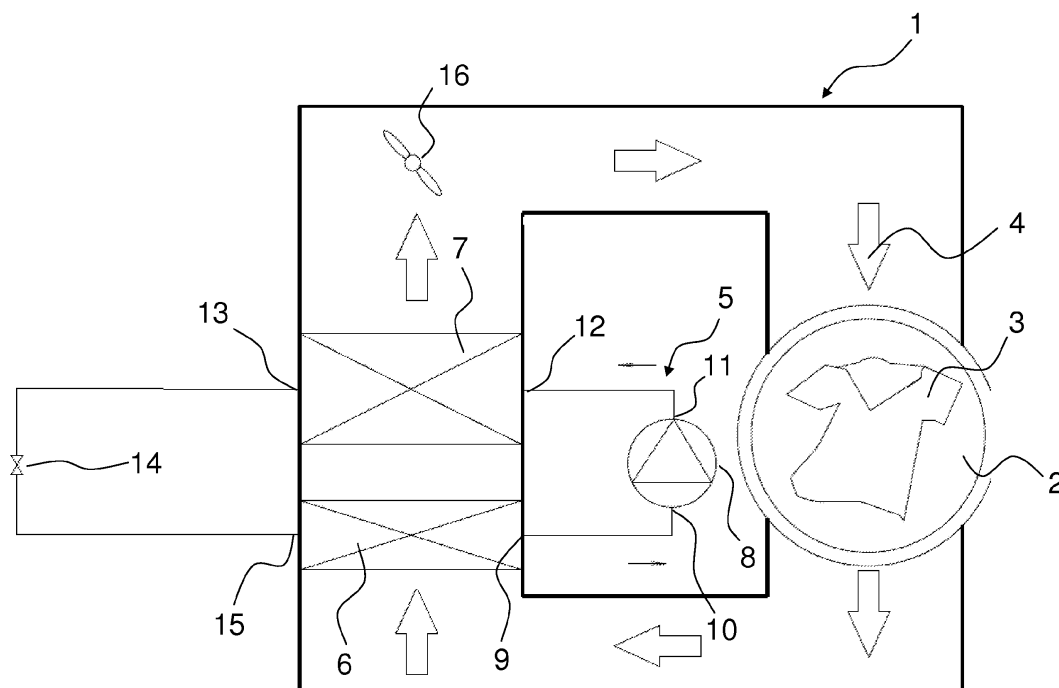
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(54) **Household appliance for drying objects**

(57) The present invention in particular is directed to a household tumble dryer 1. In order to obtain satisfactory energy efficiency and environmental compatibility, a household appliance 1 is proposed that comprises a drying chamber 2 adapted to accommodate therein objects (3) to be dried, and a first circuit for impinging the drying

chamber 2 with a drying medium 4, and further comprising a heat pump 5 with a second circuit for circulating a heat exchange medium, wherein the first and second circuit being coupled in a heat exchanging manner, and wherein the heat exchange medium being of hydro-fluoro-olefine type.



Figure

Description

[0001] The present application is directed to a household appliance for drying objects, in particular laundry.

[0002] Appliances for drying laundry, such as tumble dryers, generally comprise a drying chamber for accommodating therein the objects to be dried. Heated and dehumidified drying medium is guided through the drying chamber. Upon passing the drying chamber and objects, the heated and dehumidified drying medium takes up humidity and at the same time cools down. The drying medium then exits the drying chamber, thereby discharging humidity from the drying chamber and the objects.

[0003] In order to improve the energy efficiency of such appliances, it is known to use heat pump technology. In this way, residual heat from the drying medium exiting the drying chamber can be extracted and transferred again to drying medium before entering the drying chamber.

[0004] Heat pumps generally operate with refrigerants as working fluids. Traditional refrigerants, such as Hydrochlorofluorocarbons (HCFC) and Hydrofluorocarbons (HFC), are known to cause damages to the environment, inter alia by their ozone-destroying properties and most of all by their high global warming potential (GWP) which is the measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. Apart from this, many conventional refrigerants can be toxic.

[0005] In general, and in particular with household appliances, it is desirable to use refrigerants being far less harmful and toxic and having a reduced impact on the environment in terms of both ozone-destroying properties and global warming potential.

[0006] It is therefore an object of the present invention to provide a household appliance for drying objects, in particular laundry, the appliance having an advantageous energy efficiency combined with at least reduced environmental hazard potential.

[0007] This object is obtained by the independent claim. Preferred embodiments result from the dependent claims.

[0008] According to independent claim 1, a household appliance for drying objects, in particular laundry, is provided, the appliance comprising a drying chamber adapted to accommodate therein the objects, and a first circuit for impinging the drying chamber with a drying medium in a circulating manner, and further comprising a heat pump with a second circuit for circulating a heat exchange medium, wherein the first and second circuit being coupled in a heat exchanging manner, and wherein the heat exchange medium being of hydro-fluoro-olefine type.

[0009] The appliance, which may in particular be a household tumble dryer, comprises a heat pump. By this, residual heat from the drying medium exhausted from the drying chamber after impinging the objects to be dried can be extracted and, by adequately operating the heat pump, reused for heating drying medium prior to entering

the drying chamber.

[0010] Hence, the appliance can be operated with advantageous energy efficiency.

[0011] It shall be noted that the drying medium can be air, in particular ambient air.

[0012] The proposed heat exchange medium is of hydro-fluoro-olefine type (HFO-type), which is particularly advantageous with respect to environmental impacts and toxicity. It has shown that the proposed type of heat exchange medium is also particularly suitable for the heat exchange process and related parameters of appliances for drying objects, such as laundry, in particular for use with tumble dryers of household application.

[0013] A further advantage is that the proposed heat exchange medium can be used as a substitute for conventional heat exchange media, such as R134a refrigerant, the latter being by far more detrimental to the environment.

[0014] Another advantage is that the proposed heat exchange medium can be used without drastic impacts on structure and construction of known appliances.

[0015] In a particularly advantageous embodiment, the hydro-fluoro-olefine type heat exchange medium comprises a tetra-fluoro-propene, in particular 1,1,1,2-tetra-fluoro-propene (also known for example as HFO-1234yf, in particular according to the formula $\text{CF}_3\text{CF}=\text{CH}_2$) and 1,1,1,3-tetra-fluoro-propene (also known for example as HFO-1234ze, in particular according to the formula $\text{CF}_3\text{CH}=\text{CHF}$). The mentioned heat exchange media are particularly suitable for use with the proposed appliances such as laundry dryers, in particular laundry tumble dryers.

[0016] In particular with household appliances as proposed herein, preferably adapted to dry objects such as laundry, e.g. laundry tumble dryers, it has been found, that excellent energy efficiency and environmental compatibility can be obtained if the heat exchange medium has at least one of preferred features mentioned below.

[0017] The heat exchange medium preferably has a critical temperature lying in the range from 90°C to 115°C. If the heat exchange medium comprises or is of $\text{CF}_3\text{CF}=\text{CH}_2$ - type, the critical temperature preferably is about 94°C. If the heat exchange medium comprises or is of $\text{CF}_3\text{CH}=\text{CHF}$ - type, the critical temperature preferably is about 110°C. The critical temperatures and temperature ranges are well suited for conditions prevailing with heat pump tumble dryers, such that safe operability of the appliance can be obtained.

[0018] The heat exchange medium preferably has a critical pressure lying in a range from 25 to 40 bar, preferably from 30 to 35 bar, in particular 33 to 34 bar. If the heat exchange medium comprises or is of $\text{CF}_3\text{CF}=\text{CH}_2$ - type, the critical pressure preferably is about 33.8 bar. The advantages mentioned beforehand apply mutatis mutandis. The heat exchange medium preferably has a nominal heat of vaporization at boiling point lying in a range from 160 to 215 kJ/kg, preferably from 175 to 200 kJ/kg. If the heat exchange medium comprises or is of

CF₃CF=CH₂ - type, the nominal heat of vaporization at boiling point preferably is about 181.9 kJ/kg. The mentioned values of the nominal heat of vaporization are particularly suitable for use with heat pump tumble dryers as proposed herein.

[0019] It is also preferred, that the heat exchange medium has a global warming potential (GWP) index lying in a range from 1 to 15, preferably from 2 to 8, more preferably from 4 to 6 (equivalent carbon dioxide, which is a quantity that describes, for a given mixture and amount of greenhouse gas, the amount of CO₂ that would have the same global warming potential, the GWP of CO₂ is by convention equal to 1). For a heat exchange medium comprising or being of CF₃CF=CH₂ - type, the GWP index may be about 4, and for a heat exchange medium comprising or being of CF₃CH=CHF - type, the GWP index may be about 6.

[0020] It is of particular advantage if the heat exchange medium has at least one of a lower flammability level (LFL) of about 6.2 Vol% and an upper flammability level (UFL) of about 12.3 Vol%. It shall be noted that the LFL and UFL mentioned herein correspond to ASTM E-681 standard. Such flammability levels are of particular advantage with respect to safety considerations related to heat pump tumble dryers.

[0021] Further, the heat exchange medium preferably has at least one of a minimum ignition energy (MIE) of more than 3000 mJ and a burning velocity (BV) of about 1.5 cm/s. Note that the MIE corresponds to ASTM E-582 standard, while the BV corresponds to ISO 817 standard.

[0022] In an advantageous embodiment of the appliance, the heat pump has a nominal cooling power between about 500 W and 3,500 W, in particular between 1,500 W and 3,500 W. Such nominal cooling power in combination with the proposed heat exchange media lead to excellent energy efficiency and drying efficiency.

[0023] In still another preferred embodiment, the heat pump comprises an evaporator heat exchanger for transferring heat from the drying medium to the heat exchange medium, and the appliance is adapted such that a nominal evaporator heat exchanger inlet temperature of the drying medium is about 30° C at the least. The mentioned heat exchanger inlet temperatures are particularly advantageous for household appliances adapted to dry objects, such as laundry, in particular with respect to energy efficiency.

[0024] In yet a further preferred embodiment, the heat pump comprises a liquefier heat exchanger for transferring heat from the heat exchange medium to the drying medium, and the appliance is adapted such that a nominal liquefier heat exchanger outlet temperature of the drying medium is about 100°C at the most. The mentioned heat exchanger outlet temperatures are particularly advantageous for household appliances adapted to dry objects, such as laundry, in particular with respect to energy efficiency.

[0025] Exemplary embodiments of the invention will be described in connection with the annexed figure which

schematically shows a heat pump dryer.

[0026] The heat pump dryer 1 comprises a drying chamber 2, preferably a rotatable drum. In operation, the drying drum 2 accommodates wet laundry 3 to be dried. For adequately drying the laundry 3, a drying medium 4, such as air, in particular comprising ambient air, is circulated through the drying drum 2 via a drying medium circuit, which, preferably forms a closed-loop circuit.

[0027] For drying the laundry 3, the drying medium 4 heated to a temperature of 100°C at the most and thereby having a comparatively low relative humidity is fed into the drying drum 2 and impinges the wet laundry 3. As a consequence, humidity of the wet laundry 3 is absorbed by the drying medium 4 thereby drying the laundry 3. As the laundry 3 in the drying drum 2 generally has a temperature lying below that of the drying medium 4 entering the drying drum 2, the drying medium 4 also cools down, for example to temperatures of about 30°C.

[0028] After having passed the drying drum 2, the drying medium 4, having a comparatively high relative humidity, exits the drying drum 2 and is further cooled down to condense excess humidity therefrom. After that, the drying medium 4 is recirculated through the drying drum 2. But before re-entering the drying drum 2, the drying medium 4 is heated up again, thereby reducing its relative humidity. For dehumidification and reheating the drying medium 4, the heat pump tumble dryer 1 comprises a heat pump unit 5. The heat pump unit 5 exemplarily comprises a heat exchange medium evaporator 6 and a heat exchange medium liquefier 7. Note that in the following, the term "refrigerant" is also used as a synonym of the term "heat exchange medium".

[0029] The heat pump unit 5 further comprises a compressor 8 interconnected between the refrigerant evaporator 6 and refrigerant liquefier 7. In more detail, a refrigerant evaporator outlet 9 is connected to a compressor inlet 10 and a compressor outlet 11 is connected to a refrigerant liquefier inlet 12.

[0030] A refrigerant liquefier outlet 13 is connected via a throttling element 14, a capillary for example, to a refrigerant evaporator inlet 15. By the heat pump unit 5 heat is transferred from the refrigerant evaporator 6 to the refrigerant liquefier 7.

[0031] In particular, a refrigerant, i. e. a heat exchange medium, circulated in the heat pump unit closed circuit is heated up at the refrigerant evaporator 6 and cooled down at the refrigerant liquefier 7.

[0032] The relatively low temperature at the refrigerant evaporator 6 is used to cool down the drying medium 4 to condensate humidity, i. e. to dehumidify the drying medium 4 exiting the drying drum 2.

[0033] The elevated temperature at the refrigerant liquefier 7 is used to reheat the drying medium 4 which in turn is then fed to the drying drum 2 for drying the laundry 3.

[0034] The heat pump unit 5 may further comprise auxiliary heat exchangers for further optimizing energy efficiency. For example, an auxiliary refrigerant evaporator

and an auxiliary refrigerant liquefier may be provided. Note that the number of auxiliary refrigerant heat exchangers can be varied from one to nearly any arbitrary number. An auxiliary refrigerant evaporator may be used to speed up the heat-up phase of the heat pump dryer and a refrigerant liquefier may be used to balance the excess of energy of the heat pump dryer.

[0035] The direction of refrigerant flow is indicated in Fig. 1 by small arrows, whilst the flow of drying medium 4 is indicated by larger and broader arrows. The heat pump tumble dryer 1 may comprise a fan 16 adapted and designed for circulating the drying medium 4 within the heat pump tumble dryer circuit.

[0036] In connection with the heat pump tumble dryer 1 described so far, it has been found, that both for energetic efficiency and for environmental compatibility, it is of considerable advantage to use a refrigerant, i.e. heat exchange medium, that is of hydro-fluoro-olefine type or at least comprises such type of refrigerant.

[0037] In particular, it has been found that hydro-fluoro-olefine comprising a tetra-fluoro-propene, in particular 1,1,1,2-tetra-fluoro-propene and/or 1,1,1,3-tetra-fluoro-propene, is well suited for use with heat exchange processes of heat pump tumble dryers 1.

[0038] Further, it has been found to be of particular advantage for heat exchange processes prevailing with the heat pump tumble dryer 1, that the heat exchange medium has at least one of the following properties:

- critical temperature of about 90 °C to 115°C;
- critical pressure of about 25 to 40 bar, preferably 30 to 35 bar, more preferably 33 to 34 bar;
- nominal heat of vaporization of about 160 to 215 kJ/kg, preferably from 175 to 200 kJ/kg;
- global warming potential index of about 1 to 15, preferably of about 2 to 8, more preferably of about 4 to 6;
- lower flammability level, according to ASTM E-681 standard, of about 6.2 Vol%;
- upper flammability level, according to ASTM E-681 standard, of about 12.3 Vol%;
- minimum ignition energy, according to ASTM E-582 standard, of more than 3000 mJ; and
- burning velocity, according to ISO 817 standard, of about 1.5 cm/s.

[0039] Further, the heat pump tumble dryer 1 can be operated in an energy efficient way, in particular in concert with a heat exchange medium as described beforehand, if at least one of

- the heat pump unit 5 has a nominal cooling power between about 500 W and 3,500 W, in particular between 1,500 W and 3,500 W;
- a nominal evaporator heat exchanger inlet temperature of the drying medium 4 is about 30° C at the least; and
- a nominal liquefier heat exchanger outlet temperature of the drying medium 4 is 100 °C at the most.

[0040] In all, it is obvious, that the proposed household appliance adapted to dry objects, in particular laundry 3, has excellent energy efficiency and environmental compatibility.

List of reference numerals

[0041]

- | | | |
|----|----|-------------------------------|
| 10 | 1 | heat pump tumble dryer |
| | 2 | drying drum |
| | 3 | laundry |
| 15 | 4 | drying medium |
| | 5 | heat pump unit |
| 20 | 6 | refrigerant evaporator |
| | 7 | refrigerant liquefier |
| | 8 | compressor |
| 25 | 9 | refrigerant evaporator outlet |
| | 10 | compressor inlet |
| 30 | 11 | compressor outlet |
| | 12 | refrigerant liquefier inlet |
| | 13 | refrigerant liquefier outlet |
| 35 | 14 | throttling element |
| | 15 | refrigerant evaporator inlet |
| 40 | 16 | fan |

Claims

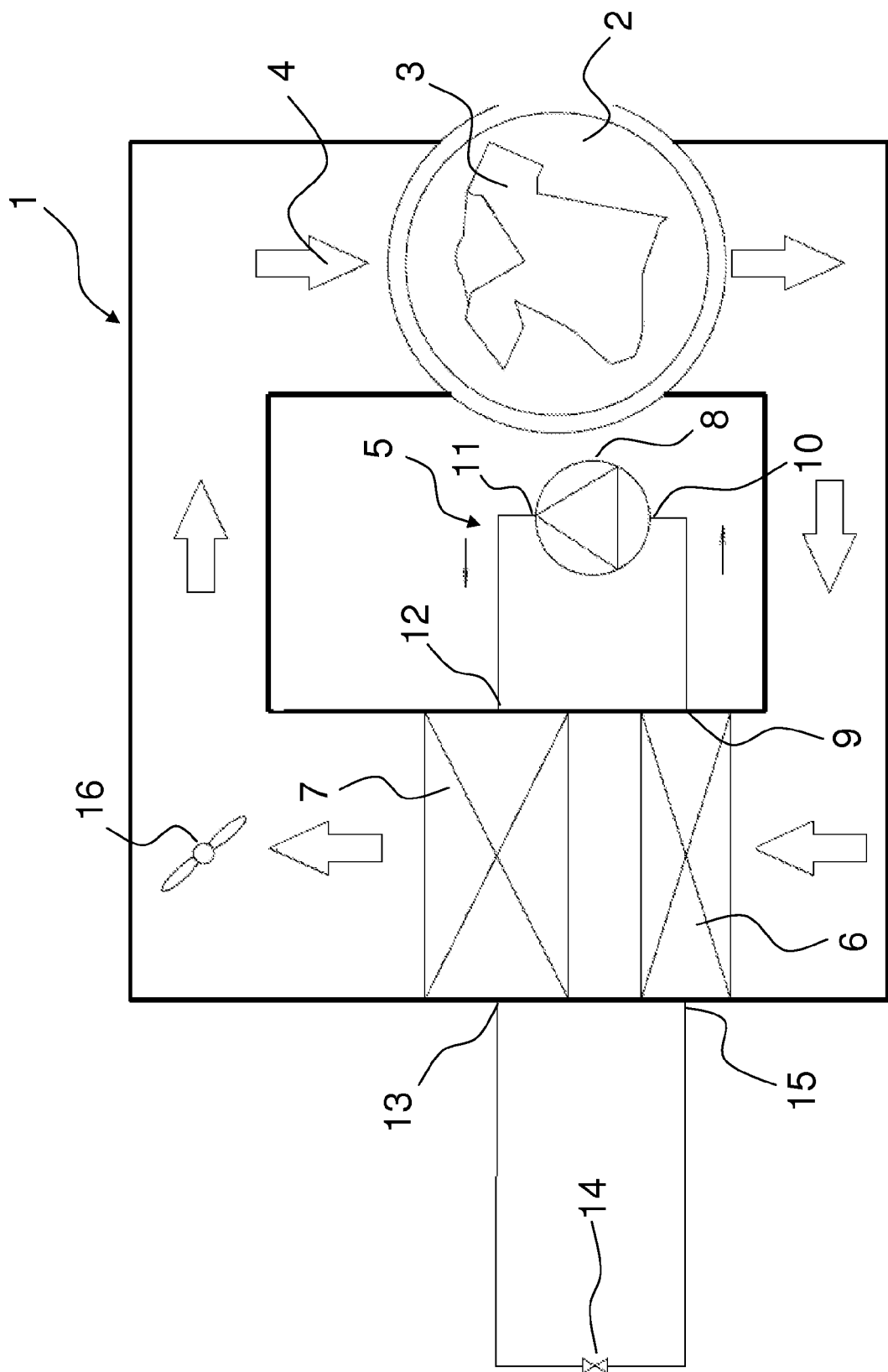
- 45 1. Household appliance (1) for drying objects, in particular laundry (3), comprising a drying chamber (2) adapted to accommodate therein the objects (3), and a first circuit for impinging the drying chamber (2) with a drying medium (4) in a circulating manner, and further comprising a heat pump (5) with a second circuit for circulating a heat exchange medium, wherein the first and second circuit being coupled in a heat exchanging manner, and wherein the heat exchange medium being of hydro-fluoro-olefine type.
- 50
- 55 2. Household appliance (1) according to claim 1, the hydro-fluoro-olefine comprising a tetra-fluoro-pro-

pene, in particular 1,1,1,2-tetra-fluoro-propene and/
Or 1,1,1,3-tetra-fluoro-propene.

3. Household appliance (1) according to claim 1 or 2,
wherein a critical temperature of the heat exchange
medium lying in a range from 90°C to 115°C. 5
4. Household appliance (1) according to at least one
of claims 1 to 3, wherein a critical pressure of the
heat exchange medium lying in a range from 25 to 40 bar,
preferably from 30 to 35 bar, in particular 33
to 34 bar. 10
5. Household appliance (1) according to at least one
of claims 1 to 4, wherein the nominal heat of vapor-
ization at boiling point of the heat exchange medium
lying in a range from 160 to 215 kJ/kg, preferably
from 175 to 200 kJ/kg. 15
6. Household appliance (1) according to at least one
of claims 1 to 5, wherein the global warming potential
index of the heat exchange medium lying in a range
from 1 to 15, preferably from 2 to 8, preferably from
4 to 6. 20
7. Household appliance (1) according to at least one
of claims 1 to 6, wherein the heat exchange medium
has at least one of a lower flammability level of about
6.2 Vol% and an upper flammability level of about
12.3 Vol%. 25 30
8. Household appliance (1) according to at least one
of claims 1 to 7, wherein the heat exchange medium
has at least one of a minimum ignition energy of more
than 3000 mJ and a burning velocity of about 1.5
cm/s. 35
9. Household appliance (1) according to at least one
of claims 1 to 8, wherein the heat pump (5) has a
nominal cooling power between about 500 W and
3,500 W, in particular between 1,500 W and 3,500 W. 40
10. Household appliance (1) according to at least one
of claims 1 to 9, wherein the heat pump (5) comprises
an evaporator heat exchanger (6) for transferring
heat from the drying medium to the heat exchange
medium, wherein the appliance (1) being adapted
such that a nominal evaporator heat exchanger inlet
temperature of the drying medium (4) being about
30° C at the least. 45 50
11. Household appliance (1) according to at least one
of claims 1 to 10, wherein the heat pump (5) com-
prises a liquefier heat exchanger (7) for transferring
heat from the heat exchange medium to the drying
medium (4), wherein the appliance (1) being adapted
such that a nominal liquefier heat exchanger outlet
temperature of the drying medium being 100 °C at 55

the most.

12. Household appliance (1) according to at least one
of claims 1 to 11, wherein the first circuit for the drying
medium forms a closed-loop circuit.



Figure



EUROPEAN SEARCH REPORT

Application Number
EP 11 15 1801

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	EP 2 067 890 A1 (BSH BOSCH SIEMENS HAUSGERÄTE [DE]) 10 June 2009 (2009-06-10) * the whole document * -----	1-12	INV. D06F58/20
			TECHNICAL FIELDS SEARCHED (IPC)
			D06F
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 5 August 2011	Examiner Diaz y Diaz-Caneja
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03.02 (P04C01)

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

EP 11 15 1801

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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05-08-2011

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2067890	A1	10-06-2009	NONE

EPO FORM P0459

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