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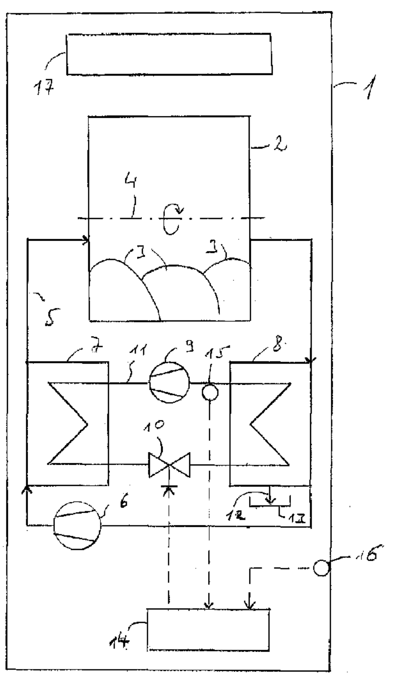

Fig. 1

(57) Abstract: The invention relates to a household appliance (1) comprising a treatment chamber (2) for treating articles (3), a process air guide (5) for guiding process air through said treatment chamber (2), said process air guide (5) comprising a blower (6) for driving the process air, a heater (7) for heating the process air and placed upstream of said treatment chamber (2), and a heat pump (7, 8, 9, 10, 11), wherein said heater (7) is a heat source (7) for transferring heat from a refrigerant circulating through said heat pump (7, 8, 9, 10, 11) to the process air, and wherein said heat pump (7, 8, 9, 10, 11) further comprises a heat sink (8) for transferring heat into the refrigerant, a compressor (9) for compressing the refrigerant, an expansion system (10) for expanding the refrigerant, and a refrigerant guide (11) for circulating the refrigerant through said heat pump (7, 8, 9, 10, 11) in a closed circuit. Said expansion system (10) has a variable restriction which may be controllable by a control unit (14) in response to signals from a sensor unit (15, 16).

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Household Appliance Comprising an Expansion System

The invention relates to a household appliance comprising a treatment chamber for treating articles, a process air guide for guiding process air through said treatment chamber, said process air guide comprising a blower for driving the process air, a heater for heating the process air and placed upstream of said treatment chamber, and a heat pump, wherein said heater is a heat source for transferring heat from a refrigerant circulating through said heat pump to the process air, and wherein said heat pump further comprises a heat sink for transferring heat into the refrigerant, a compressor for compressing the refrigerant, an expansion system for expanding the refrigerant, and a refrigerant guide for circulating the refrigerant through said heat pump in a closed circuit.

A household appliance of this generic type is disclosed in WO 2008/107266 A1. The appliance disclosed is a household laundry dryer whose heat pump is a compressor-type heat pump which is characterized by having a refrigerant which is guided in a closed refrigerant guide. To effect an absorption of heat into the associated heat sink, the refrigerant is made to evaporate in the heat sink, and to release heat from the associated heat source, the refrigerant is made to liquefy in the heat source. To effect the transport of heat and have the evaporation and liquefaction processes to occur at appropriate temperatures, the gaseous refrigerant is compressed as it passes from the heat sink to the heat source, and the liquid refrigerant is expanded in an expansion system as it returns from the heat source to the heat sink. According to the cited document, a special selection of the compressor comprised by the heat pump and the refrigerant is made.

In document WO 2008/119611 A1, a cleaning device to clean a heat sink of a heat pump in a laundry dryer is disclosed. A heat sink in a laundry dryer is subject to operational degradation by small particulates comprising fragments of fibers and the like, normally termed lint or fluff, and abstracted from the laundry being dried by the process air. According to usual practice, a lint filter is placed into the process air guide upstream of the heat sink to catch a major portion of the lint from the process air. Yet, a small but considerable fraction of the lint will escape from being caught by the lint filter, and precipitate onto the heat sink together with condensate formed from humidity contained in the process air which is formed upon extracting heat from the process air.

While the two documents cited above each relate to a household appliance having a process air guide which is substantially closed in itself to guide the process air in a substantially closed circuit, WO 2008/110449 A1 exhibits a household appliance having a heat pump and having a process air guide which is partly open.

According to documents WO 2008/119608 A2 and WO 2008/086933 A1, a heat pump may be applied in a household appliance in addition to more usual electric or gas burner heaters and air-to-air heat exchangers. Such appliances may be termed “hybrids”.

According to document WO 2007/141166 A1, the heat sink and the heat source of a heat pump comprised by a household appliance can be arranged in a forked process air guide to have the process air to pass them as two part flows in parallel, in contrast to more usual practice requiring the undivided process air flow to pass the heat sink and the heat source in sequence.

Insofar as they relate to applying a compressor-type heat pump to a household appliance, and also in accordance with general practice with household appliances with compressor-type heat pumps as they are marketed at the time of establishing the right of priority to the invention disclosed hereinbelow, the heat pumps are equipped with components whose operational characteristics are fixed by dimensioning and construction. Normal use of such household appliances will occur under a variety of ambient conditions defined by the placement of the appliances and the seasons of the year. In addition, normal use in itself will also incur a variety of operating conditions. For example, operation of a laundry dryer with a heat pump will include a starting phase wherein the components of the appliance and the laundry to be dried itself will be brought to their proper operating temperatures, a quasi-stationary phase where the majority of the drying operation is performed, and a terminating phase where the laundry is almost as dry as desired and the extraction of the residual humidity from the laundry needs to rise the temperature of the process air passing the laundry above the level that had been continued through the quasi-stationary phase. Accordingly, a layout of the heat pump needs to be found which allows to operate the heat pump through all of these phases, while coping with variable ambient conditions as well.

It is an object of the present invention to present a development of the appliance as defined in the preamble of this application which overcomes the disadvantages specified.

In order to comply with this and other objects, a household appliance is specified in the independent claim attached. Preferred embodiments of the household appliance according to the present invention are specified in dependent claims and the subsequent specification.

Accordingly, there is specified, in accordance with the invention, a household appliance comprising a treatment chamber for treating articles, a process air guide for guiding process air through said treatment chamber, said process air guide comprising a blower for driving the process air, a heater for heating the process air and placed upstream of said treatment chamber, and a heat pump, wherein said heater is a heat source for transferring heat from a refrigerant circulating through said heat pump to the process air, and wherein said heat pump further comprises a heat sink for transferring heat into the refrigerant, a compressor for compressing the refrigerant, an expansion system for expanding the refrigerant, and a refrigerant guide for circulating the refrigerant through said heat pump in a closed circuit. In addition, said expansion system has a variable restriction.

According to the invention, a variable expansion system replaces known expansion systems with fixed dimensional and constructional parameters, to yield operational flexibility for the household appliance in view of adaptation to varying ambient and operational requirements.

An effective operational parameter of the expansion system is a restriction which is measured as a pressure drop generated by the liquid refrigerant flowing through at a nominal temperature and a nominal mass flow. In the case of an expansion system given by a single expander, different embodiments as ejector or orifice on one hand and capillaries of various lengths and various diameters on the other hand may result in the same restriction. Accordingly, the invention imposes no a priori limitation on constructional details of the expansion system. It may be noted that variable expansion systems are known for non-pertinent applications as in cooling appliances.

The invention will allow a household appliance to adapt to a variety of ambient temperatures, to assure proper operation at ambient temperatures varying between 5 °C and 35 °C, with 23 °C being a nominal temperature. In addition, changes in operational parameters occurring through a process for treating articles in the appliance may be adapted to, by modifying characteristics of the heat pump as given by the restriction of the expansion system, to better adapt the functional layout and settings of the heat pump to pertinent operational conditions and thus obtain better operational efficiency and possibly shorter duration of treatment processes.

In accordance with a preferred embodiment of the invention, the household appliance comprises a control unit connected to said expansion system and a sensor unit associated to said heat pump, for controlling the restriction of said expansion system in response to signals communicated to said control unit by said sensor unit. Thereby, the expansion system may be controlled in response to pertinent operational conditions of the heat pump. To enable and effect such control, a plurality of options is given. As a first example, the expansion system may have a restriction that is controllable by electronic means. In such case, the control unit may be a standalone electronic circuit, or it may be included in a system control unit which performs overall control of the appliance, including interfacing with a user to display operational information, select operational programs for treating of articles placed into the appliance, and set operational parameters for such programs.

In accordance with a more preferred embodiment of the invention, said sensor unit specified in the preceding chapter comprises a state sensor for sensing a state of said heat pump. Yet more preferred said state sensor is a temperature sensor for sensing a process temperature within said refrigerant guide. Still more preferred, the process temperature is a temperature of the refrigerant upon exiting said heat sink, and said control unit is preset to control said expansion system for retaining a given superheat in the refrigerant exiting said heat sink. In this context, it is noted that normal operation of the appliance including the heat sink wherein the refrigerant enters the heat sink in a liquid state, to be evaporated while flowing through the heat sink to form a gas, which gas will be heated by a certain amount to a temperature which is above the boiling temperature of the refrigerant under the pressure condition given. The difference from the boiling temperature to the temperature of the gaseous refrigerant as it exits the heat sink is defined to be the superheat. A heat pump as known to be incorporated into a laundry dryer appliance will not allow for any control through its normal use during a drying process. Thus, the superheat will change under changing operational conditions. By applying an arrangement as presented here, control of the superheat including control to retain the superheat at a given and desired value has become possible.

In accordance with another preferred embodiment of the invention, said sensor unit comprises an ambient temperature sensor for sensing an ambient temperature of said appliance. This enables to take the pertinent ambient conditions into account for operating the appliance including the heat pump, and it also allows for modification of the mode of operation in response to ambient conditions. As any heat pump will require an amount of energy input for its operation which must in turn be dissipated to its ambient, the ambient temperature is a functional parameter for the heat pump as it affects that dissipation. According to the invention, the ambient temperature may be accounted for in operating the heat pump. More preferred in this regard, said control unit is preset to set said restriction to a nominal value if the ambient temperature is essentially equal to a given normal ambient temperature, and wherein said control unit is preset to set said restriction to a value exceeding said nominal value if the ambient temperature is essentially different from said normal ambient temperature. A preferred setting for operation may provide to set the expansion system to a normal restriction at a normal ambient temperature which may be a usual ambient temperature to be encountered in a normal household, and to increase the restriction over the normal restriction both at ambient temperatures higher and lower than the normal ambient temperature. When the ambient temperature is excessively high, a thermal load on the heat pump is high, and the compressor in the heat pump may run into unduly high thermal load. By increasing the restriction, a mass flow of the refrigerant circulating through the heat pump will be reduced, and the load on the compressor reduced concurrently. When the ambient temperature is excessively low, thermal load on the heat pump is low. In turn, full evaporation of the refrigerant as it flows through the heat sink may be difficult to ascertain. By increasing the restriction and thereby reducing the mass flow of the refrigerant circulating, input of liquid to be evaporated into the heat sink is reduced, thereby alleviating the problem to ascertain full evaporation.

In accordance with a further preferred embodiment of the invention, said expansion system comprises at least two expansion units which are variably engageable into said refrigerant guide by said control unit. This enables to apply an expansion system wherein a selection between several fixed values for the restriction is possible by simple switching. More preferred said expansion system comprises an expansion unit which comprises a first expander and a valve controllable by said control unit and connected in series. More preferred the expansion system may include a second expander connected in parallel to said expansion unit. Such embodiment makes sure that no switching state resulting in a complete shutoff of the expansion system can occur, thereby providing a measure of operational safety. Yet more preferred a plurality of expansion units connected in parallel to one another may be provided in the expansion system, thereby providing n extended range of variability of the restriction, to improve adaptability of the system to various operational requirements. Still more preferred said expansion unit comprises a multiplicity of first expanders, wherein said first expanders are connected in parallel to one another through a multi-way distribution valve controllable by said control unit, thus simplifying the switching means while retaining a high measure of variability.

In accordance with yet another preferred embodiment of the invention, said expansion system is a variable expansion device controllable by said control unit. As a preferred example, said expansion device comprises a variable expansion valve. In particular, said expansion valve is a thermostatic expansion device. Still more preferred, said thermostatic expansion device has an associated temperature sensor coupled to said process air guide at an exit of said treatment chamber for sensing an air temperature of the process air upon exiting said treatment chamber, and wherein said thermostatic expansion device is provided to vary said restriction from a relatively low restriction at a low air temperature to a relatively high restriction at a high air temperature. Furthermore preferred, said expansion system is a multiplicity of thermostatic expansion devices, and wherein said thermostatic expansion devices are connected in parallel to one another through a multi-way distribution valve controllable by said control unit.

According to the invention, variable valves for use as expansion units are preferred though they may require providing an electronic control which may be a standalone unit or a part of an electronic system control unit as explained hereinabove. Yet, a variable expansion device may be applied which is marketed as a self-contained unit including sensor and control means, to vary a restriction in response to a state variable, which is in general a temperature, as sensed by the sensor means. In this regard the sensor means may be applied as a state sensor or ambient temperature sensor as explained hereinabove. In addition, further modes of control may be implemented by using such variable expansion device. As a precaution it is noted that the term “thermostatic expansion device” is familiar to a person of ordinary skill in the art due to the application of such devices in self-controlled refrigeration circuits in freezers or refrigerators. Yet, the property of being “thermostatic” is not really a property of the expansion device itself but of the complete refrigeration circuit that includes the device.

As an example, a typical drying process as executed in a common laundry drying appliance may be considered. Immediately after initiation the drying process will start with heating phase where the components included in the process air circuit will change their temperatures to operating values, and the articles to be dried will be heated to an elevated operational temperature. To keep the duration of the process short it is desired to keep the heating phase short. Accordingly, a relatively high restriction in the expansion system is desired to attain a relatively high pressure of the refrigerant in the heat source leading to an elevated condensation temperature of the refrigerant, to an elevated temperature difference between the refrigerant and the process air in the heat source and to an increased heat transfer into the process air in consequence. In addition, the highly restricted flow of refrigerant will reduce the amount to be evaporated in the heat sink, and the resultant cooling of the process air in the heat sink as well. As soon as the components have reached their respective operating temperatures, a quasi-stationary phase will follow on the heating phase. In the quasi-stationary phase, only small changes in operating temperatures will occur, and the restriction of the expansion system may be set to a reduced nominal value – that may still be dependent on ambient conditions as explained hereinabove. As the drying process approaches its end, all humidity has been evaporated from the surfaces of the articles to be dried, and remaining humidity must be extracted from deep within the textile fibres making up the articles. This puts an additional load on the process which manifests itself in another rise in operational temperature of the articles, the components in their vicinity and the process air flowing from them. This rise in temperature indicates a transition from the quasi-stationary phase to a terminal phase of the drying process. In general, this phase is short with few influence of the duration of the drying process overall. Yet, an increased restriction would be desirable to lower the evaporation temperature of the refrigerant in the heat sink and improve the extraction of humidity from the process air. Accordingly, and neglecting the desires for the terminating phase specified above, a self-contained variable expansion device, or a plurality of such devices, in particular selectable via distribution valve in response to ambient conditions, may be applied in the inventive appliance for such purpose. The function of such device would be to reduce the restriction upon an increase in temperature. If the requirements particular for the terminal phase should be taken into account as well, addition of a switchable expander as elaborated hereinabove may be effective.

In accordance with yet a further preferred embodiment of the invention, said process air guide within the inventive appliance is substantially closed in itself to guide the process air in a substantially closed circuit, thereby rendering the appliance a closed-circuit dryer or condensation-type dryer.

In accordance with still another preferred embodiment of the invention, said heat sink is a cooler placed in said process air guide for cooling the process air after exiting said treatment chamber for extracting humidity from said process air, again in compliance with the features of a condensation-type dryer. More preferred said cooler has a condensate collector placed hereunder for collecting condensate precipitating from the process air within said cooler, to collect the humidity abstracted from the articles by operating the inventive appliance.

In accordance with still a further preferred embodiment of the invention, said treatment chamber is a rotatable drum for tumbling the articles placed therein for treatment.

Further details and advantages of the invention are apparent from the subsequent description of preferred embodiments which are also shown in the figures of the accompanying drawing. In particular:

- Fig.1 shows a household appliance as embodied in a laundry dryer and having an expansion device with variable restriction;
- Fig. 2 shows a first embodiment of an expansion device having a variable restriction;

Fig. 3 shows a second embodiment of an expansion device having a variable restriction; and

Fig. 4 as variable expansion device incorporated into an expansion device having a variable restriction.

In the drawing, Fig. 1 shows a household appliance 1 which is incorporated as a laundry dryer 1. The laundry dryer 1 comprises a treatment chamber 2 which is configured as a drum 2, wherein the articles 3 to be dried, presently pieces of laundry 3, are placed. Details and accessories like a door and a drive as commonly associated with such drum 2 are not shown for the sake of simplicity. Drum 2 is rotatable about an axis 4 for tumbling the pieces of laundry 3 through process air flowing along to extract humidity from the pieces of laundry 3. Process air for drying the pieces of laundry 3 is guided by a process air guide 5. Process air guide 5 comprises a blower 6 which drives the process air in a substantially closed circuit. In this regards, “substantially closed” means that process air guide 5 is kept at a pressure substantially equal to the pressure in the ambient of the appliance 1, but is not hermetically sealed against the ambient however without any functionally relevant leak by which air should be exchanged between process air guide 5 and ambient. The process air guide 5 includes a heater 7 or heat source 7 placed upstream of drum 2 for heating the process air prior to entering drum 2. Downstream of drum 2, the process air guide 5 includes a cooler 8 or heat sink 8 wherein heat is extracted from the process air after leaving drum 2. Process air guide 5 may include further components according to common practice. In particular, temperature sensors and a lint filter may be present but are not shown in Fig. 1 for the sake of simplicity.

Heat source 7 and heat sink 8 are embodied as heat exchangers 7 and 8 to exchange heat with the process air passing through. Heat source 7 and heat sink 8 are also included in a heat pump 7, 8, 9, 10, 11. This provides to recover heat extracted from the process air in the heat sink 8 by pumping such heat to the heat source 7 where it is transferred back into the process air. While such heat pump process cannot function on its own, but necessarily needs an input of additional energy to be effective as provided by the laws of thermodynamics, such process greatly reduces the energy input required to evaporate all humidity from the pieces of laundry 3 contained in drum 2. The heat pump 7, 8, 9, 10, 11 includes, beside heat source 7 and heat sink 8, a compressor 9 for compressing a refrigerant which is circulated through the heat pump 7, 8, 9, 10, 11 in a closed circuit, an expansion system 10 to effect a reduction of internal pressure within the circulating refrigerant and a refrigerant guide 11 which guides the refrigerant as it is circulated. The refrigerant may be selected from a variety of chemical compounds and compositions which are known in the art to be suitable for the purpose. In particular, the refrigerant may be a hydrocarbon compound like propane (R290 in terms of the commonly used ASHRAE standards), a fluorinated hydrocarbon compound like R134a and R152a or a mixture of such fluorinated hydrocarbon compounds like R407C and R410A; the compounds indicated in terms of the commonly used ASHRAE standards. In operation, the refrigerant will exit the heat sink 8 in gaseous form, to be guided to the compressor 9 by refrigerant guide 11. The compressor 9 will compress the gaseous refrigerant and forward it to heat source 7. In the heat source 7, the refrigerant will release heat to the process air flowing through, and condense to liquid form in consequence. After exiting heat source 7, the liquid refrigerant passes through the expansion system 10 which is familiarly embodied as a throttle or restriction. The most common form of a device which is usable as an expansion system 10 is a capillary 10, namely a tube of considerable length with a very small cross section. Expansion system 10 serves to reduce the internal pressure of the liquid refrigerant. Subsequently, the refrigerant enters heat sink 8 in liquid form, and will absorb heat from the process air flowing through. The heat absorbed into the liquid refrigerant will make the refrigerant evaporate to gaseous form, thus completing a whole cycle of circulation. Due to the differences in internal pressure of the refrigerant between heat source 7 and heat sink 8, the condensation of the refrigerant will occur at a considerably higher temperature then its evaporation, as a prerequisite for the heat pump process which serves to operate the laundry dryer 1.

Extraction of humidity from the pieces of laundry 3 is done by the process air, and humidity picked up by the process air will be extracted from the process air in the heat sink 8. There, heat is extracted from the process air, causing the humidity contained therein in the form of vapour to condense and form a condensate which precipitates from the process air. This condensate is collected in condensate line 12 and conveyed to condensate collector 13. After completion of a drying process, condensate collector 13 may be emptied, and the condensate disposed of in any suitable manner.

A special feature of the appliance shown in Fig. 1 is that the expansion system 10 has a restriction defined to determine the flow rate of a condensate at given pressure and temperature conditions which is variable by operation of a dedicated control unit 14. To that end, control unit 14 is connected to a sensor unit 15, 16 comprising a state sensor 15 to determine a temperature of the refrigerant as it exits heat sink 8 and an ambient temperature sensor 16 which determines a temperature of the ambient of the appliance 1. In accordance to signals obtained from these sensors 15 and 16, control unit 14 will set the restriction of expansion system 10 to vary the operating conditions of heat pump 7, 8, 9, 10, 11 in response to these signals.

The expansion system 10 with its variable restriction allows appliance 1 to adapt to a variety of ambient temperatures, to assure proper operation at ambient temperatures varying between 5 °C and 35 °C, with 23 °C being a nominal temperature. In addition, changes in operational parameters occurring through a process for treating the articles 3 in the appliance 1 may be adapted to, by modifying characteristics of the heat pump 6, 7, 8, 9, 10, 11 as given by the restriction of the expansion system 10, to better adapt the functional layout and settings of the heat pump 6, 7, 8, 9, 10, 11 to pertinent operational conditions and thus obtain better operational efficiency and possibly shorter duration of treatment processes.

The state sensor 15 is a temperature sensor 15 for sensing a process temperature within refrigerant guide 11. The process temperature is a temperature of the refrigerant upon exiting heat sink 8, and control unit 14 is preset to control the expansion system 10 for retaining a given superheat in the refrigerant exiting heat sink 8. In this context, it is noted that normal operation of the appliance 1 including the heat sink 8 wherein the refrigerant enters the heat sink 8 in a liquid state, to be evaporated while flowing through the heat sink 8 to form a gas, which gas will be heated by a certain amount to a temperature which is above the boiling temperature of the refrigerant under the pressure condition given. The difference from the boiling temperature to the temperature of the gaseous refrigerant as it exits heat sink 8 is defined to be the superheat. Generally, the superheat will change under changing operational conditions. By applying an arrangement as presented here, control of the superheat including control to retain the superheat at a given and desired value is possible.

Further, the sensor unit 15, 16 comprises ambient temperature sensor 16 for sensing an ambient temperature of appliance 1. This enables to take the pertinent ambient conditions into account for operating the appliance 1 including heat pump 6, 7, 8, 9, 10, 11, and it also allows for modification of the mode of operation in response to ambient conditions. As the heat pump 6, 7, 8, 9, 10, 11 necessarily requires an amount of energy input for its operation which must in turn be dissipated to its ambient, the ambient temperature is a functional parameter for operation as it affects that dissipation. Presently, the ambient temperature may be accounted for in operating the heat pump 6, 7, 8, 9, 10 by stetting the restriction at the expansion device 10. In particular, control unit 14 is preset to set the restriction to a nominal value if the ambient temperature is essentially equal to a given normal ambient temperature, and control unit 14 is preset to set said restriction to a value exceeding said nominal value if the ambient temperature is essentially different from said normal ambient temperature. A preferred setting for operation may provide to set the expansion system 10 to a normal restriction at a normal ambient temperature which may be a usual ambient temperature to be encountered in a normal household, and to increase the restriction over the normal restriction both at ambient temperatures higher and lower than the normal ambient temperature. When the ambient temperature is excessively high, a thermal load on the heat pump 6, 7, 8, 9, 10, 11 is high, and compressor 9 may run into unduly high thermal load. By increasing the restriction, a mass flow of the refrigerant circulating through heat pump 6, 7, 8, 9, 10, 11 will be reduced, and the load on compressor 9 reduced concurrently. When the ambient temperature is excessively low, thermal load on the heat pump 6, 7, 8, 9, 10, 11 is low. In turn, full evaporation of the refrigerant as it flows through the heat sink 8 may be difficult to ascertain. By increasing the restriction and thereby reducing the mass flow of the refrigerant circulating, input of liquid to be evaporated into the heat sink 8 is reduced, thereby alleviating the problem to ascertain full evaporation.

As to constructional details of the expansion system 10 and the control unit 14, common practice as known by persons of ordinary skill in the art provides numerous options. For example, the expansion system 10 may be embodied as a valve 10 whose restriction may be varied continuously by electronic means. In such case, control unit 14 could be an electronic circuit which could operate independently of other components of the appliance 1, or, as an alternative, be incorporated into an electronic appliance control unit 17 which is commonly used both for operational control of appliance 1 as well as for interfacing with a user or operator by displaying process-related information and receiving through suitable input means, control information for selecting a program for a predefined drying process or setting a parameter relating to such program. Display and input means are not shown for the sake of simplicity. Common practice also provides for self-contained units including an expansion system 10 and a control unit 14, for example in the form of a “thermostatic expansion device”, which are commonly used in freezers and refrigerators.

Fig. 2 shows an example of an expansion system 10 comprising two expansion units 18, 19, each of which comprising a first expander 18, possibly a capillary 18, and a switch valve 19 connected in series. Both expansion units 18, 19 are connected in parallel, and a second expander 20 is connected in parallel to both units 18, 19. Both switch valves 19 may be switched from closed to open by control unit 14, thus providing a total of four different restrictions available to define operating parameters for the heat pump 7, 8, 9, 10, 11 as exemplified in Fig. 1.

Fig. 3 shows an alternative expansion system 10 for use in refrigerant guide 11 between heat source 7 and heat sink 8. Again, the expansion system 10 comprises expansion units 18, each made up from a single expander 18, and all expanders 18 connected to a distribution valve 21 controllable by control unit 14 which may selectively invoke each of the expanders 18 for use in the heat pump 7, 8, 9, 10, 11 as exemplified in Fig. 1.

Fig. 4 shows another example of a variable expansion system 10 incorporated into a thermostatic expansion device. This device includes a continuously variable valve 10 included into refrigerant guide 11. Further, it includes a process air temperature sensor 22 which is presently connected to the process air guide 5 to sense a temperature of the process air as it exits the treatment chamber 2. The process air temperature sensor 22 is presently simply a bulb which is filled with a working fluid 24 that will serve to sense a temperature that it is exposed to. In principle, the temperature sensor 22 may be placed at any location as deemed useful for its operation to control the variable valve 10. The temperature sensor 22 is connected to a chamber 14 serving as the control unit 14. Within the chamber 14, a movable diaphragm 23 separates a room filled by the working fluid and communicating with the interior of the bulb 22 from a part of the room filled by air. The diaphragm 23 contacts a pushrod 25 which in turn serves to set the restriction of the variable valve 10. As the process air temperature at the exit of drum 2 and sensed by bulb 22 changes, the working fluid 24 will expand or contract and move diaphragm 23 correspondingly. This movement is transmitted to the variable valve 10 by pushrod 25, and will cause a change of the restriction of the variable valve 10 in response to a change in temperature of the process air. Thereby, an adaptation of the operation of the heat pump 7, 8, 9, 10, 11 in response to the process air temperature at the exit of drum 2 is effected.

Immediately after initiation, a typical drying process executed in drying appliance 1 will start with heating phase where the components included in the process air circuit 2, 5, 6, 7, 8 will change their temperatures from ambient temperatures to operating values, and the articles 3 to be dried will be heated to an elevated operational temperature. To keep the duration of the process short it is desired to keep the heating phase short. Accordingly, a relatively high restriction in expansion system 10 is set to attain a relatively high pressure of the refrigerant in the heat source 7 leading to an elevated condensation temperature of the refrigerant, to an elevated temperature difference between the refrigerant and the process air in the heat source 7 and to an increased heat transfer into the process air in consequence. In addition, the highly restricted flow of refrigerant will reduce the amount to be evaporated in heat sink 8, and the resultant cooling of the process air in heat sink 8 as well. As soon as the components 2, 5, 6, 7, 8 have reached their respective operating temperatures, a quasi-stationary phase will follow on the heating phase in the drying process. In the quasi-stationary phase, only small changes in operating temperatures will occur, and the restriction of the expansion system 10 may be set to a reduced nominal value – that may still be dependent on ambient conditions as explained herein above. As the drying process approaches its end, all humidity has been evaporated from the surfaces of the articles 3 to be dried, and remaining humidity must be extracted from deep within the textile fibres making up the articles 3. This puts an additional load on the process which manifests itself in another rise in operational temperature of the articles 3, the components 2 in their vicinity and the process air flowing from them. This rise in temperature indicates a transition from the quasi-stationary phase to a terminal phase of the drying process. In general, this phase is short with few influence of the duration of the drying process overall. Yet, an increased restriction would be desirable to lower the evaporation temperature of the refrigerant in the heat sink 8 and improve the extraction of humidity from the process air. Accordingly, and neglecting the desires for the terminating phase specified above, a self-contained variable expansion device 10, or a plurality of such devices 10, in particular selectable via distribution valve 21 in response to ambient conditions, may be applied in appliance 1 for such purpose.

The function of such device 10 would be to reduce the restriction upon an increase in temperature. If the requirements particular for the terminal phase should be taken into account as well, addition of a switchable expander as shown in Fig. 4 may be effective.

As to the process air guide 5 within the appliance 1 detailed herein, it is substantially closed in itself to guide the process air in a substantially closed circuit, thereby rendering the appliance 1 a closed-circuit dryer or condensation-type dryer. Yet, this should not be regarded as a mandatory feature. The novel features disclosed herein will lend themselves well to another type of appliance wherein the process air guide 5 is not substantially closed in itself, or where even plural process air circuits 5 parallel to each other are implemented.

To conclude, it follows that the present invention as defined in the accompanying claims and as detailed and exemplified hereinabove enables novel embodiments of a household appliance, in particular a laundry dryer, and a heat pump contained therein, to further improve the effectivity and the duration of treatment processes scheduled for use in such appliance.

LIST OF REFERENCE NUMERALS

1 Household appliance, laundry dryer
2 Treatment chamber, drum
3 Articles to be dried, laundry
4 Axis of rotation
5 Process air guide
6 Blower
7 Heater, heat source
8 Cooler, heat sink
9 Compressor
10 Expansion system
11 Refrigerant guide
12 Condensate line
13 Condensate collector
14 Expansion system control unit
15 State sensor, refrigerant temperature sensor
16 Ambient temperature sensor
17 Appliance control unit
18 First expander
19 Switch valve
20 Second expander
21 Distribution valve
22 Process air temperature sensor
23 Diaphragm
24 Working fluid
25 Pushrod

CLAIMS

1. Household appliance (1) comprising a treatment chamber (2) for treating articles (3), a process air guide (5) for guiding process air through said treatment chamber (2), said process air guide (5) comprising a blower (6) for driving the process air, a heater (7) for heating the process air and placed upstream of said treatment chamber (2), and a heat pump (7, 8, 9, 10, 11), wherein said heater (7) is a heat source (7) for transferring heat from a refrigerant circulating through said heat pump (7, 8, 9, 10, 11) to the process air, and wherein said heat pump (7, 8, 9, 10, 11) further comprises a heat sink (8) for transferring heat into the refrigerant, a compressor (9) for compressing the refrigerant, an expansion system (10) for expanding the refrigerant, and a refrigerant guide (11) for circulating the refrigerant through said heat pump (7, 8, 9, 10, 11) in a closed circuit, **characterized in that** said expansion system (10) has a variable restriction.

2. Household appliance according to claim 1, comprising a control unit (14) connected to said expansion system (10) and a sensor unit (15, 16) associated to said heat pump (7, 8, 9, 10, 11), for controlling the restriction of said expansion system (10) in response to signals communicated to said control unit (14) by said sensor unit (15, 16).

3. Household appliance (1) according to claim 2, wherein said sensor unit (15, 16) comprises a state sensor (15) for sensing a state of said heat pump (7, 8, 9, 10, 11).

4. Household appliance according to claim 3, wherein said state sensor (15) is a temperature sensor (15) for sensing a process temperature within said refrigerant guide (11).

5. Household appliance according to claim 4, wherein the process temperature is a temperature of the refrigerant upon exiting said heat sink (8), and wherein said control unit (14) is preset to control said expansion system (10) for retaining a given superheat in the refrigerant exiting said heat sink (8).

6. Household appliance (1) according to one of claims 2 to 5, wherein said sensor unit (15, 16) comprises an ambient temperature sensor (16) for sensing an ambient temperature of said appliance (1).

7. Household appliance (1) according to claim 6, wherein said control unit (14) is preset to set said restriction to a nominal value if the ambient temperature is essentially equal to a given normal ambient temperature, and wherein said control unit (14) is preset to set said restriction to a value exceeding said nominal value if the ambient temperature is essentially different from said normal ambient temperature.

8. Household appliance (1) according to one of the preceding claims, wherein said expansion system (10) comprises at least two expansion units (18, 19, 21) which are variably engageable into said refrigerant guide (11) by said control unit (14).

9. Household appliance (1) according to claim 8, wherein said expansion system (10) comprises an expansion unit (18, 19, 21) which comprises a first expander (18) and a valve (19) controllable by said control unit (14) and connected in series.

10. Household appliance (1) according to claim 9, comprising a second expander (20) connected in parallel to said expansion unit (18, 19, 21).

11. Household appliance (1) according to one of claims 9 and 10, comprising a plurality of expansion units (18, 19, 21) connected in parallel to one another.

12. Household appliance (1) according to one of claims 9 and 10, wherein said expansion unit (18, 19, 21) comprises a multiplicity of first expanders (18), wherein said first expanders (18) are connected in parallel to one another through a multi-way distribution valve (21) controllable by said control unit (14).

13. Household appliance (1) according to one of claims 1 to 7, wherein said expansion system (10) is a variable expansion device (10) controllable by said control unit (14).

14. Household appliance (1) according to claim 13, wherein said expansion system (10) comprises a variable expansion valve (10).

15. Household appliance (1) according to one of claims 13 and 14, wherein said expansion valve (10) is a thermostatic expansion device (10).

16. Household appliance according to claim 15, wherein said thermostatic expansion device (10) has an associated temperature sensor (22) coupled to said process air guide (5) at an exit of said treatment chamber (2) for sensing an air temperature of the process air upon exiting said treatment chamber (2), and wherein said thermostatic expansion device (10) is provided to vary said restriction from a relatively low restriction at a low air temperature to a relatively high restriction at a high air temperature.

17. Household appliance (1) according to one of claims 13 to 16, wherein said expansion system (10) is a multiplicity of thermostatic expansion devices (10), and wherein said thermostatic expansion devices (10) are connected in parallel to one another through a multi-way distribution valve (21) controllable by said control unit (14).

18. Household appliance (1) according to one of the preceding claims, wherein said process air guide (5) is substantially closed in itself.

19. Household appliance (1) according to claim 17, wherein said heat sink (8) is a cooler (8) placed in said process air guide (5) for cooling the process air after exiting said treatment chamber for extracting humidity from said process air.

20. Household appliance according to claim 19, wherein said cooler (8) has a condensate collector (13) placed thereunder for collecting condensate precipitating from the process air within said cooler (8).

21. Household appliance (1) according to one of the preceding claims, wherein said treatment chamber (2) is a rotatable drum (2) for tumbling the articles (3) placed therein for treatment.

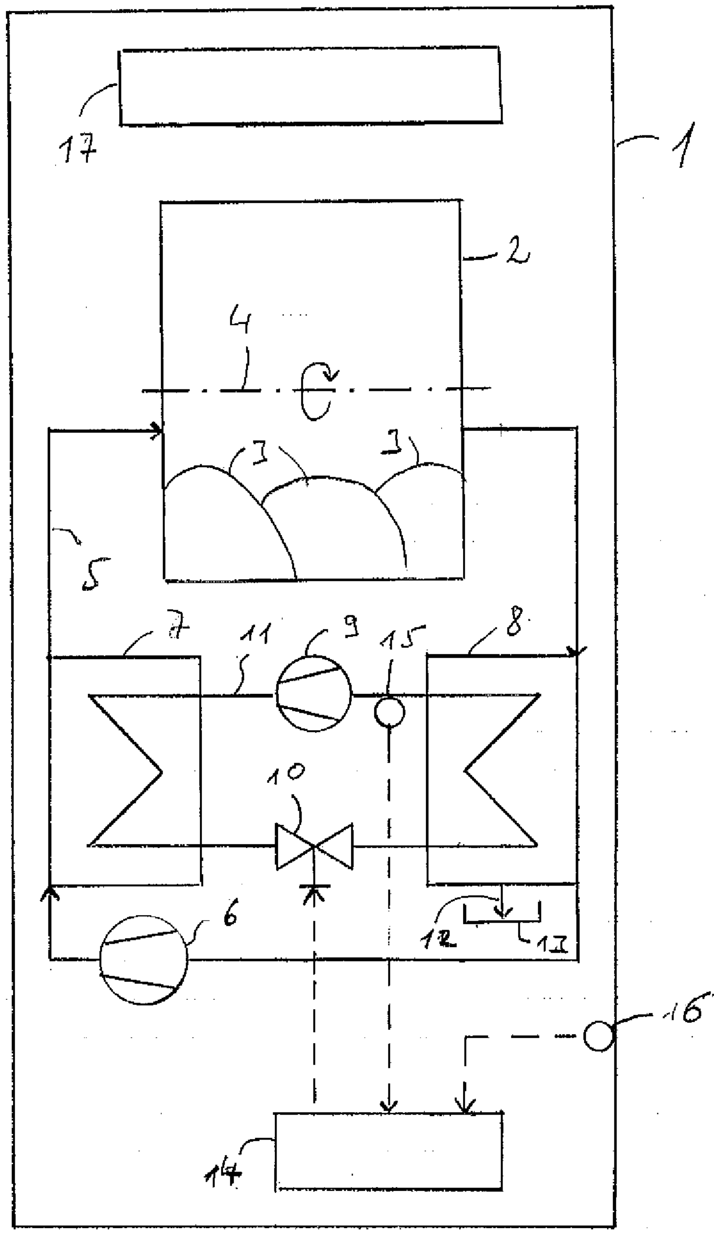

Fig. 1

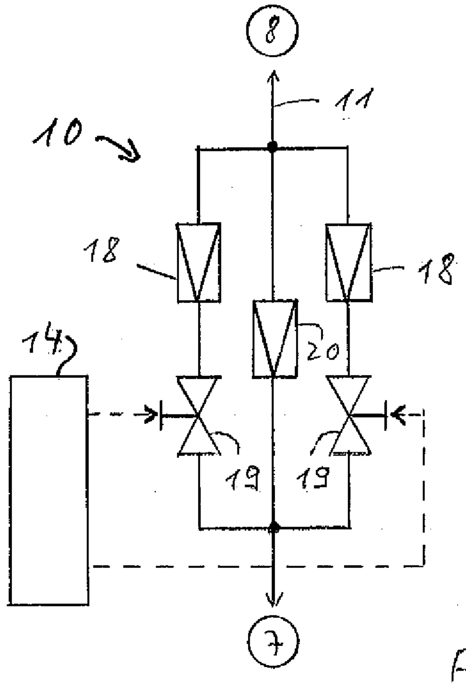

Fig. 2

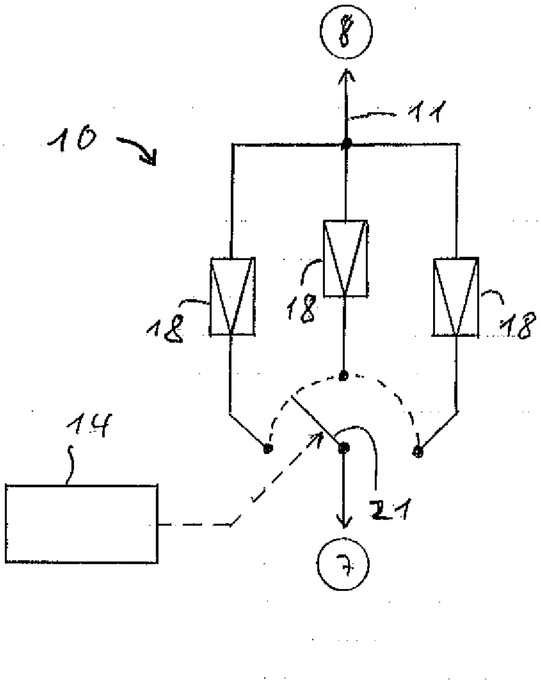

Fig. 3

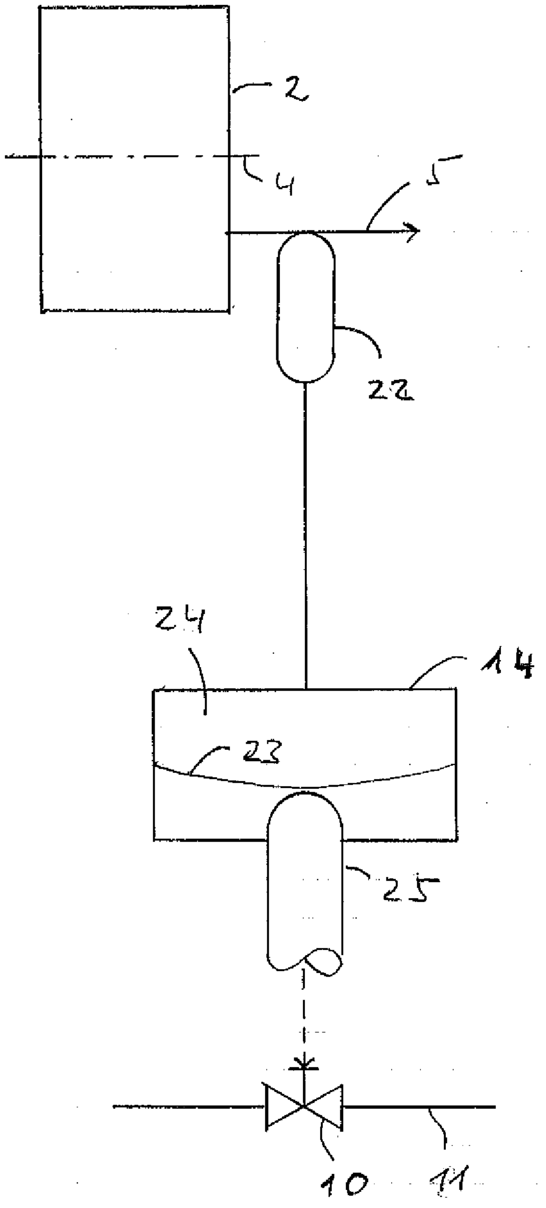

Fig. 4