

Method for cooling an airstream

Technical field of the invention

The present invention relates to a method and an apparatus for cooling an airstream.

Prior art

Dehumidifying systems are known in domestic technology. Here it is possible to use an apparatus as disclosed by EP 1 521 040. From an airstream flowing through a first cavity, humidity is extracted via a water-permeable and/or water vapour-permeable membrane. Prior to the heat exchange with the airstream to be cooled and the dehumidified return airstream, a liquid is then added to this return air and evaporated in order to lower the temperature of the return airstream upstream of the heat exchanger (evaporative cooling).

EP 0 959 307 discloses a sorption plate heat exchanger, whose dilute sorbent is collected by means of a complex procedure, reprocessed (desorption by heating and subsequent cooling) and then passed back to the plate heat exchanger.

WO 03/091632 discloses a dew point condenser, in which two airstreams are guided past a heat-conducting wall. In the process, water is absorbed from the one airstream in a unilateral hygroscopic coating of the wall and fed back to the medium by evaporation. This results in cooling of the other airstream behind the wall.

US 6,434,963 describes a cooling and heating apparatus comprising a central heat exchanger. At the outlets of the heat exchanger, a closed cooling circuit is provided which further cools the supply air, the return air being further heated thereby. In the prior art apparatus, water is added to the spent compartment air so as to cool it upstream of the heat exchanger.

Downstream of the heat exchanger, more water is added to the return air, advantageously by means of an evaporative pad, before the return air passes through the heating section of the cooling circuit. On the supply-air side, water condensing on the cooling section of the cooling circuit is collected and is recycled to the evaporative pad. An external water supply is also present.

US 2005/056042 describes a similar apparatus as US 6,434,963, in which water is injected into the return air above the heat exchanger, thus causing the walls of the heat exchanger to be wetted. Collecting the water below the heat exchanger permits a partial water cycle, with the exception of the water vapour remaining in the return air.

Description of the invention

Based on this prior art, the object of the invention is to improve an apparatus of the type mentioned at the outset in such a way that wholly or partially self-sufficient operation of the apparatus is thereby enabled.

This object is achieved by a method and an apparatus having the features of claim 1 and of claim 4, respectively.

Accordingly, a method of cooling a first airstream comprises the steps of dehumidifying a second airstream, injecting water into the dehumidified second airstream so as to cool the second airstream and passing the first and the cooled second airstream through a heat exchanger so as to cool the first airstream. In the process of dehumidifying the second airstream, condensate is recovered which is reused in the injection step.

Owing to physical givens, injection comprises evaporation of the injected water.

For the purpose of increasing self-sufficiency, particularly in mobile installations, there is the additional option of further condensate to be injected being recovered by means of dehumidifying free ambient air.

An apparatus for cooling a first airstream according to the present invention comprises an air dehumidifying apparatus for at least one second airstream having a water-permeable and/or water vapour-permeable structure which via pumping means is connected to a condensate separator, a cooling system through which the dehumidified second airstream can be passed, and a heat exchanger through which the two airstreams can be passed so as to cool the first airstream. The water recovered from the condensate separator is passed into the cooling system for the purpose of injecting it (evaporation).

In a further air dehumidifying apparatus, of the apparatus according to the invention, further condensate can be recovered from the cooled first airstream.

An additional air dehumidifying apparatus can be used to recover further condensate from the ambient air.

The additional apparatus can be arranged on a vehicle. In this arrangement, the airstream along the additional air dehumidifying apparatus is generated by moving the vehicle.

The vehicle is preferably a motor vehicle or a trailer of a motor vehicle, particularly preferably a dormobile, a caravan, a lorry, a trailer, a ship or an aircraft.

Brief description of the drawing

The invention is explained below in more detail with reference to the drawing, in which: Figure 1 shows a schematic depiction of an embodiment of the present invention.

Description of an embodiment

Figure 1, in a schematic depiction, shows an apparatus according to the present invention. The function of the apparatus according to the invention is explained with reference to this schematic depiction. The apparatus for cooling compartment air is provided with a multiplicity of individual appliances which are known to those skilled in the art and are therefore not discussed here in any detail.

In an airstream referred to as the first airstream, outside air 50 is passed, as supply air 51, via various elements into a compartment 60. The outside air 50, which in the summer often has an outside temperature that it would be desirable to lower, is typically passed via a coarse particle filter 38A and/or an electrostatic filter 39B into a heat exchanger 40, a possible design of the heat exchanger being that of a plate heat exchanger in accordance with WO 2004/085946. In the heat exchanger 40, the outside air 50 undergoes cooling by the cooled airstream 55" advantageously passed countercurrently, and re-emerges as cooled airstream 50'. The cooled airstream 50' is then advantageously passed into a first air dehumidifying apparatus 1. In this first air dehumidifying apparatus 1, humidity is extracted from the cooled airstream 50' which now, compared with the warmer outside air 50, has a higher relative atmospheric humidity, and the cooled airstream 50' leaves the air dehumidifying apparatus 1 as a cooled and dehumidified airstream 50". By means of a fan 41, the cooled and dehumidified airstream 50" is supplied as supply air 51 to an advantageously closed compartment 60 in which the desired climatic conditions are achieved. Accordingly, the supply air 51 has a lower temperature than the outside air 50.

In an airstream referred to as the second airstream, return air 55 from a compartment 60 is discharged as exhaust air 56 to the environment via various elements to be described hereinafter. The return air 55, which has an interior temperature, is typically passed from the closed compartment 60 through a coarse particle filter 38B and/or an electrostatic filter 39B. The return air 55 enters a second air dehumidifying apparatus 2 and leaves this as a dehumidified airstream 55'. By means of a fan 41, the dehumidified airstream 55' is fed to a cooling system 20. In the cooling system, the dehumidified airstream 55' is cooled. Consequently, a cooled airstream 55" escapes from the cooling system. In the heat exchanger 40, heat exchange takes place between the cooled airstream 55" and the warm outside air 50. After heat exchange has taken place, the now warmer airstream 55", which previously has

been cooled, leaves the heat exchanger as exhaust air 56 which is then discharged to the environment.

The two air dehumidifying apparatuses 1, 2 can be of a design in accordance with EP 1 521 040 or a comparable apparatus. The air dehumidifying apparatuses 1, 2 for example comprise a first cavity 4 in each case, which is separated from a second cavity 5 by means of a water-permeable and/or water vapour-permeable membrane 3. The abovedescribed airstreams in each case flow through a separate first cavity 4.

In other embodiments, two separate air dehumidifying apparatuses 1, 2 can be provided, or just the dehumidifying apparatus 2 is provided for the second airstream 55. As indicated below, a further air dehumidifying apparatus not shown in the drawings can also be provided, which operates on ambient air, i.e. dehumidifies the latter. The purpose of this, however, is not the dehumidified ambient air but the recovery of condensate. This can be achieved by means of a separate condensation water separator or the condensation water separator 11 explained in conjunction with the dehumidifying apparatuses 1, 2.

By means of a partial vacuum, e.g. generated by a vacuum pump 10, a partial vacuum is generated in a manifold 6 and in the second cavity 5 of the air dehumidifying apparatus 1, 2. Via this manifold 6, which is connected to the second cavity 5 of the air dehumidifying apparatuses 1, 2, this more humid air is discharged. The partial vacuum causes a mixture 100 of air and water vapour to be drawn into the condensation water separator 11. By means of the condensation water separator 11, the mixture 100 is separated into air 101 and water 102. The air 101 is discharged into the environment, and the water 102 is fed via a conduit 12 to a pressure booster pump 13. Via a further conduit section 14, the pressurized water 103 is supplied to the cooling system 20.

In the cooling system 20, of a design, for example, in accordance with WO 2004/085946, the pressurized water 103 is atomized by means of one or more nozzles, increasing the humidity of the dehumidified airstream 55'. In the process, the relative humidity of the exhaust air increases, and as a result of the evaporation heat to be absorbed the temperature of the dehumidified airstream 55' drops, resulting in the cooled airstream 55". Excess water is discharged to the environment. Alternatively, it can be collected with the intention of recycling it into the cooling system 20.

Recovering condensation water 102 by dehumidifying an airstream 50' and/or 55' and subsequently recycling it into the cooling system 20, enables wholly or partially self-sufficient operation of the apparatus according to the present invention.

Installing an additional air dehumidifying apparatus (not shown in the drawings) allows the recovery of further condensate. In this arrangement, the apparatus does not include the cavity 4, the membrane 3 therefore being directly contiguous to an airstream. This apparatus is particularly advantageous if the apparatus is mounted on a motor vehicle or a trailer of a motor vehicle, for example a dormobile, a caravan, a lorry, a trailer, or an aircraft. The airstream in this case is an airstream flowing past which is generated by the relative wind of the vehicle. In doing so condensate for injection purposes is recovered from the free ambient air.

All the said airstreams, apart from the airstream flowing past, are guided in conduits or ducts known to those skilled in the art.

In winter, the installation can also be used to heat and humidify the airstream 50, 50', 50". The airstream 55', 55" is then not cooled in the cooling system 20. In the heat exchanger 40, the airstream 50 can accordingly be heated by means of warmer return air 55". Moreover, humidity is abstracted from the return air 55 in the second air dehumidifying apparatus 2 and is fed via the manifold 6 into the first air dehumidifying apparatus 1. Via the first air dehumidifying apparatus 1, humidity of the airstream 50' is augmented. The apparatus can be combined with a caravan heating installation or a motor vehicle heating installation.

The apparatus according to Figure 1 can be cascaded in a simple manner. The simplest cascade is achieved by arranging onto the ducts guiding the airstreams 50 and 56 a further apparatus inclusively comprising the filters 38A, 39B and the heat exchanger 40 as shown in the depiction on the left-hand side of Figure 1 and up to and including fan 41 and filters 38B, 39B as shown on the right-hand side of Figure 1 in such a manner that the duct for the supply air 51 is connected to the said duct 50 and the duct of the return air 55 is connected to the exhaust air of the previous apparatus. It is thus possible, in a number of steps, to all in all lower the temperature to a greater extent. Each of the apparatuses can then be self-sufficient apart from its power supply leads, the ducts 101 for the discharge of the air are advantageously combined. The advantage of this cascading arrangement is its simplicity, since apparatuses of identical construction can be used. Should a unit fail, operation of the apparatus as a whole is not affected per se, since, for example, the fans 41 of the other apparatuses will continue to maintain air movement and, if a water circuit were to fail, cooling of the other cascade elements continues to function.

In a simpler cascading arrangement, cascading is limited to the air dehumidifying apparatus 2 together with the injection system 20 and the heat exchanger 40. Fans 41, filters 38A, 39A, 38B, 39B and water separator 11 likewise may be provided as a single item for the entire apparatus. In that case, the return air 55 then successively passes through the assemblies 2, 20

and 40, whereas the outside air 50 in each case is passed solely through the second duct of the heat exchanger 40, optionally also through the air dehumidifying apparatus 1.

List of reference symbols

1	Air dehumidifying apparatus
2	Air dehumidifying apparatus
3	Water-permeable and/or water vapour-permeable membrane
4	First cavity
5	Second cavity
6	Manifold
10	Vacuum pump
11	Condensation water separator
12	Conduit
13	Pressure booster pump
14	Conduit
20	Cooling system
38A	Coarse particle filter
38B	Electrostatic filter
39A	Coarse particle filter
39B	Electrostatic filter
40	Heat exchanger
41	Fan
50	Outside air
50'	Cooled airstream
50"	Dehumidified, cooled airstream
51	Supply air
55	Return air
55'	Dehumidified airstream
55"	Cooled airstream
56	Exhaust air
60	Compartment
100	Mixture of air and condensation water
101	Air
102	Water
103	Pressurized water

Claims

1. Method for cooling and dehumidifying a first air stream (50, 50', 50'', 51), the method comprising the steps of:
 - A) passing a second air stream (55, 55', 55'', 56) through a first coarse particle filter (38B) and a first electro-filter (39B) for cleaning the second air stream and through a first cavity (4) of an air-dehumidifying apparatus (2), which is separated by a water vapor permeable structure from a second cavity (5) of the air-dehumidifying apparatus (2), for dehumidifying the cleaned second air stream and obtaining water as condensate;
 - B) injecting water into the dehumidified second air stream (55') for cooling the second air stream,
 - C) passing the first air stream (50) through a second coarse particle filter (38A) and a second electro-filter (39A) for cleaning the first air stream; and
 - D) passing the first air stream (50) cleaned in step C and the second air stream (55'') cleaned, dehumidified and cooled in the steps A and B through a heat exchanger for cooling the first air stream (50), wherein
water obtained when dehumidifying the second air stream (55) in step A is used in step B for injecting.

2. Method according to claim 1, wherein the first air stream (50') cleaned and cooled in steps C and D is passed through a first cavity (4) of a further air-dehumidifying apparatus (1), which first cavity is separated by a water vapor permeable structure from a second cavity (5) of the further air-dehumidifying apparatus (2), for dehumidifying the cleaned and cooled first air stream and for obtaining water as condensate, and wherein also the water obtained in doing so is used in step B for injecting.

3. Method according to claim 1 or 2, wherein free ambient air is dehumidified in order to obtain further water as condensate for step B.

4. Apparatus for cooling a first air stream (50, 50', 50'', 51), comprising
a second coarse particle filter (38A) and a second electro-filter (39A) for cleaning the first air stream,

a first coarse particle filter (38B) and a first electro-filter (39B) for cleaning a second air stream (55, 55', 55'', 56),

an air-dehumidifying apparatus (2) for the cleaned second air stream, having a first cavity (4) and a second cavity (5), which are separated from each other by a water vapor permeable structure (3), wherein the second air stream may flow through the first cavity,

a condensation water separator (11), which is connected via a manifold (6) with the second cavity (5) of the air-dehumidifying apparatus (2) for the second air stream,

pump means (10) arranged in the manifold,

a cooling system (20), through which the dehumidified second air stream (55') may flow,

a conduit (12) and a pressure booster pump (13) arranged in the conduit for feeding water obtained in the condensation water separator (11) to the cooling system (20), and

a heat exchanger (40) for exchanging heat between the cleaned first air stream (50) and the cleaned, dehumidified and cooled second air stream (55'').

5. Apparatus according to claim 4, further comprising an additional air-dehumidifying apparatus (1) for the first air stream, having a first cavity (4) and a second cavity (5), which are separated from each other by a water vapor permeable structure (3), wherein the first air

stream may flow through the first cavity, wherein the second cavity (5) of the additional air-dehumidifying apparatus (1) for the first air stream is connected with the manifold (6).

6. Apparatus according to claim 4 or 5, further comprising a further additional air-dehumidifying apparatus for obtaining further water from ambient air and supplying to the cooling system (20).

7. Apparatus according to any of claims 4 to 6, further comprising
an additional air-dehumidifying apparatus for the second air stream, having a first cavity (4) and a second cavity (5), which are separated from each other by a water vapor permeable structure (3), wherein the second air stream may flow through the first cavity,
an additional cooling system (20) for the second air stream,
an additional heat exchanger (40) for the exchange of heat between the first air stream and the second air stream.

8. Apparatus according to claim 6, further comprising
an additional air-dehumidifying apparatus for the first air stream, with a first cavity (4) and a second cavity (5), which are separated from each other by a water vapor permeable structure (3), wherein the first air stream may flow through the first cavity.

9. Vehicle comprising an apparatus according to claim 6.

10. Vehicle according to claim 9, wherein the vehicle is a motor vehicle, a trailer of a motor vehicle, a dormobile, a caravan, a lorry, a trailer, a ship or an aircraft.