



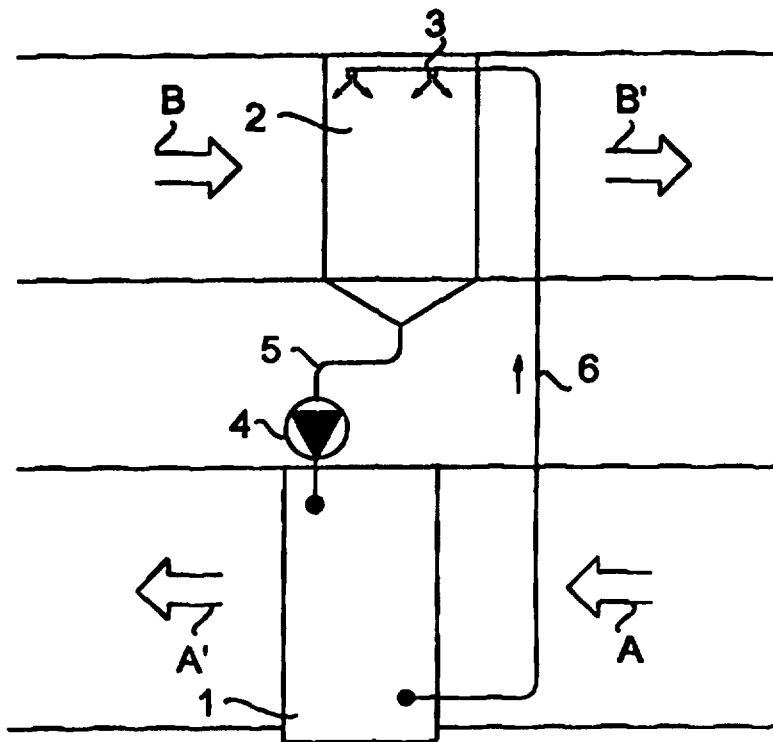
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<p>(21) International Application Number: PCT/FI96/00564</p> <p>(22) International Filing Date: 23 October 1996 (23.10.96)</p> <p>(30) Priority Data: 955112 26 October 1995 (26.10.95) FI</p> <p>(71) Applicant (for all designated States except US): ABB INSTAL-LAATIOT OY [FI/FI]; Iso-Iivarintie, FIN-21530 Paimio (FI).</p> <p>(72) Inventor; and (75) Inventor/Applicant (for US only): SARIN, Dan [FI/FI]; Tilkankuja 6 C 21, FIN-00300 Helsinki (FI).</p> <p>(74) Agent: OY KOLSTER AB; Iso Roobertinkatu 23, P.O. Box 148, FIN-00121 Helsinki (FI).</p>	<p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).</p> <p><b>Published</b> With international search report.</p>	

(54) Title: METHOD AND ARRANGEMENT FOR CONVEYING HEAT FROM EXHAUST AIR INTO INLET AIR BY A HEAT EXCHANGER VIA WHICH NON-FREEZING HEAT TRANSFER LIQUID IS CIRCULATED

## (57) Abstract

The invention relates to a method and arrangement for conveying heat, in which heating or cooling capacity is conveyed from the exhaust air (B-B') of ventilation or air conditioning of standard rooms into inlet air (A-A') by means of an inlet air heat exchanger, via which non-freezing heat transfer liquid is circulated. For reducing the investment costs, the non-freezing heat transfer liquid is brought into direct contact with the exhaust air (B-B').



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**METHOD AND ARRANGEMENT FOR CONVEYING HEAT FROM EXHAUST AIR INTO INLET AIR BY A HEAT EXCHANGER VIA WHICH NON-FREEZING HEAT TRANSFER LIQUID IS CIRCULATED.**

5 The invention relates to a method for conveying heat, in which heating or cooling power is conveyed from the exhaust air of ventilation or air conditioning of standard rooms into inlet air by means of an inlet air heat exchanger, via which non-freezing heat transfer liquid is circulated. The invention further relates to a arrangement for conveying heat.

10 In the ventilation installations particularly in temperate and frigid climate zones, it is nowadays common to recover heat from low-temperature exhaust air, i.e. having a temperature of 18 - 27 °C, and transfer it to inlet air by means of a specific heat recovery unit. During the last few years, it has become more common to use these units in summer for recovering cooling power from the exhaust air, which is remarkably colder than the outdoor air in buildings that are equipped with a refrigerating system. This effect may be intensified by humidifying the exhaust air before it passes to the recovery unit. Water vaporizing into the air thus binds heat, which will drop the temperature of the air and increase the recovered cooling power. Such a so-called indirect evaporative cooling is disclosed e.g. in Finnish Patent No. 67253.

25 A variety of types of installations have been used for recovery, the commonest being a plate heat exchanger operating on a cross-flow principle in which inlet and exhaust air flows are directed to adjacent narrow ducts through whose partition the heat is conveyed; a liquid-circulation system in which the heat from the exhaust air is bound in a heat exchanger to a heat transfer liquid which is pumped through the pipeline to an inlet air heat exchanger in which it releases its heat; and a so-called regenerative system

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in which heat is bound in an exhaust duct to a solid substance which is transferred mechanically to an inlet air duct to release its heat. The commonest application of the last-mentioned system is a rotating drum, exhaust air being arranged to flow through one half and inlet air through the other half of said drum.

By means of these installations, it is possible to cut down the need of thermal capacity by 50 - 60 % in a heating situation and the cooling capacity by 30 -100 % depending on the type of equipment, building and the thermal loads on the building. Consequently, they are nowadays commonly used especially in large buildings.

However, the installations are attended by serious drawbacks. The most remarkable of them is a poor heat transfer co-efficient, which results in the fact that large heat surfaces must be used in order to recover a sufficient amount of energy. The costs are thus high and the payback time long. The poor heat transfer co-efficient is mainly due to the fact that in all types of installations, heat must pass twice through the boundary of air and a metal or some other solid substance. The so-called surface resistance is thus dozens of times higher compared with the case in which heat is transferred e.g. through a boundary of a liquid and a metal.

When large heat surfaces must be used, the equipment is heavy and large in size, due to which the room costs and installation costs are also high, as well as the maintenance costs e.g. due to poor cleansability. An even more serious drawback is the fact that large heat surfaces inevitably result in a high flow resistance of air in the installation. The flow resistance is usually as high as the total flow resistance of the rest of the air conditioning

apparatus altogether. The fan and the motor of the air conditioning apparatus must be dimensioned large. This increases the costs and the demand for space. A yet more serious drawback is a high consumption of electricity, which increases the running costs and further lengthens the payback time. The consumption of electricity is an important contributory factor therein that heat recovery has not become widespread e.g. in air-conditioning of multi-storey buildings.

A high flow resistance has remarkable side-effects. The noise level of the fan increases, for instance, and the sound attenuators must be dimensioned for a higher degree of attenuation, which increases the costs. A larger motor of the fan requires larger auxiliary equipments, such as wirings, contactors, thermal relays etc. The coupling power and costs are also higher compared with a smaller engine.

Finnish Patent applications No. 933,534 and 954,508 disclose installations in which the heat transfer co-efficient is improved by forming a liquid layer on a heat transfer surface of the air side of an exhaust air heat exchanger. The surface resistance is thus reduced, and freezing of the surface may thus also be prevented in the installation in accordance with Finnish patent application No. 954,508. The surface resistance and the air flow resistance caused by the exchanger still exist, however.

It is an object of the invention to provide a method and arrangement that allow eliminating the drawbacks of the prior art and also cutting down the investment costs to a considerable extent. This is achieved with the invention. The invention is based on the idea that instead of moistening the heat surface, the heat exchanger of the exhaust side of a liquid-circulation system is entirely removed and a non-

freezing liquid is brought into a direct contact with low-temperature exhaust air. The method according to the invention is characterized in that the non-freezing heat transfer liquid is brought into direct contact with exhaust air. The arrangement of the invention, in turn, is characterized by comprising means that are arranged to bring the heat transfer liquid into direct contact with the exhaust air.

The major advantage of the invention is the fact that there are no investment costs caused by the heat exchanger, and the pressure loss caused by the heat exchanger, as well as the negative consequences caused by the pressure loss are eliminated. It is easy to form a large surface of liquid by spraying it into the air in a manner which is known per se from air humidifiers and equipment for producing condensing water or process water from hot process gases at power plants, or by employing prior art air humidifiers whose price is remarkably lower than that of the air exchanger. It must also be noted that in prior art systems the humidifier is required in any case for recovering cooling power in summer. With reference to the above-mentioned production equipments of condensing water at power plants, it can be stated herein that such solutions are operated with outdoor air and are thus able to produce only cooling power. The water is always warm and its temperature will not drop below 0 °C in any circumstances. It can be stated herein with reference to the technique employed for the production of process water that the equipment is only suited for producing hot process water from hot process gases.

When the heat transfer liquid has a direct and close contact with air, heat exchange is highly efficient, and the temperature difference between the liquid and the air remains slight. Consequently, the

temperature difference between liquid and air increases on the inlet air side, and the amount of the recovered thermal energy also increases. According to calculations, the efficiency of the recovery increases to more than 80 %, if it is 70 % in conventional systems, that is, the amount of energy required from outside decreases by more than 30 %. Alternatively, it is possible to cut down the size of the heat exchanger on the inlet side and maintain the degree of recovery unchanged, which will reduce the costs and the pressure loss etc. The drawback of the prior art solutions is also the fact that the degree of recovery must be limited in peak load situations because the heat transfer surfaces on the exhaust side will freeze if it is attempted to cool the exhaust air below 0 °C. In the solution of the invention, there is no need to make the limitation.

In the following, the invention will be disclosed in more detail with reference to the embodiments disclosed in the attached drawing, in which

Figure 1 shows a schematic diagram of a first embodiment of the arrangement according to the invention,

Figure 2 shows a schematic diagram of a second embodiment of the arrangement according to the invention,

Figure 3 shows a schematic diagram of a third embodiment of the arrangement according to the invention, and

Figure 4 shows a schematic diagram of a fourth embodiment of the arrangement according to the invention.

Figure 1 shows the simplest embodiment of the invention. Inlet air A-A' flows through an inlet air heat exchanger 1 and exhaust air B-B' through a

humidification chamber 2 placed into an exhaust duct. In accordance with the basic idea of the invention, there is no heat exchanger in the exhaust duct, but non-freezing heat transfer liquid is brought into direct contact with the exhaust air flow B-B'.

The heat transfer liquid collected at the bottom of the humidification chamber 2 is sucked by means of a pump 4 via a pipe 5 and pressed via the inlet air exchanger 1 and a pipe 6 to nozzles 3, by means of which the heat transfer liquid is sprayed to the humidification chamber 2, in which it comes into contact with the exhaust air.

In the embodiment of Figure 1, the flow of the heat transfer liquid mist and air is a so-called cross-flow, that is, the flow directions are perpendicular to each other. However, greater temperature differences and a better degree of recovery are achieved by means of a counter-flow application according to Figure 2, in which the heat transfer liquid and the exhaust air flow in the opposite directions in the contact situation. In Figure 2, the same reference numerals have been used at the corresponding points as those in Figure 1. The counter-flow application can naturally also be achieved in a way known per se by connecting two or more humidifiers in series.

The counter-flow solution must often be implemented in accordance with Figure 3 so that the flows take place in the vertical direction for making the heat transfer liquid settle in order to be collected. In Figure 3, a humidifier cell 7, as well as an exhaust air duct 8 and an inlet air duct 9 are shown instead of the nozzles. Instead of the humidifier cell 7, any prior art humidification device may be used, as well as any sprayer device may be used instead of nozzles.



The exhaust air may contain impurities that may come into the heat transfer liquid and weaken its heat transfer characteristics and/or cause blockages, wearing etc. For avoiding this drawback, an exhaust air  
5 filter 10 is shown in Figure 3, by means of which filter most of the impurities may be removed. In addition, it is possible to design a distillation funnel 11 of the heat transfer liquid in a form of a settling chamber in accordance with Figure 3, provide  
10 the suction pipe 5 with a liquid filter 12 and use other prior art methods for removing impurities, and design the installation so that it is easily cleansable etc.

Heat transfer liquids are usually aqueous  
15 solutions because in winter their temperature usually drops below 0 °C, and the heat transfer liquid must thus be non-freezing. When the liquid comes into direct contact with air, water and/or blend component usually evaporate from it in summer, and water is condensed  
20 from the exhaust air in winter when the exhaust air cools down. This usually results in a reduced volume and an increased concentration of liquid in summer and in an increased volume and a reduced concentration of liquid in winter.

25 Methods for controlling the concentration are disclosed in Finnish Patent application No. 954,508, which is incorporated herein by reference. As to the summertime, it can be stated that if, in addition to water, the blend component of the heat transfer liquid  
30 is also volatile, it is advantageous to drain the heat transfer liquid from the heat transfer circuit and use water instead. The drainage may be carried out as a single operation manually or automatically by means of a pump 4 controlled e.g. by an outdoor air thermostat  
35 or in some other way known per se.

The overall arrangement for controlling the concentration and the temperatures may be e.g. in accordance with Figure 4. Figure 4 relates to a case in which the heat transfer liquid is not replaced, that is, it is a question of an inorganic saline solution whose blend component does not evaporate. The arrangement of Figure 4 corresponds to Figure 3 in other respects, but the heat exchanger 1 of the inlet side is also connected to the circuit as a counter-flow connection, which improves the efficiency of the recovery. If the heat transfer liquid is hygroscopic, it is more advantageous to replace the liquid in summer because the hygroscopicity reduces evaporation, and thus the cooling capacity.

Figure 4 also shows a tap water supply 13, from which the water evaporating from the solution is replaced via a valve 14. The valve 14 may be controlled by a level or concentration sensor placed in the distillation funnel 11, or the valve 14 itself may be a float valve, or some other prior art technique for controlling the level and/or concentration may be employed. These are not shown in Figure 4. Instead of tap water network, it is of course possible to obtain water from a container via a manual valve or a control valve, to fill the distillation funnel 11 manually, to control the operation by means of a timer etc. All these prior art solutions of course fall within the scope of the invention.

For winter-time use Figure 4 shows as an example an installation 15 - 19 operating on the evaporating principle. A three-way valve 15 controlled by a concentration sensor placed e.g. in the distillation funnel 11 or in pipes 5 or 6 or by some other control device directs part of the flow of pipe 5 or 6 via a heat exchanger 16 to a boiling vessel 17,

in which water is vaporized from the solution e.g. by means of an electric resistance 18, the water being then directed to an exchanger 16, at which it condenses and preheats the heat transfer liquid passing to the boiling vessel 17. The cooled water is passed to a sewer, to a distillation container, or the like. The concentrated solution is directed from the boiling vessel 17 via a valve 19 to pipe 5. The valve 19 may be controlled by a concentration or level sensor, a timer or any other prior art device.

Likewise, the heat source of evaporation may be a gas or oil burner, steam etc. It is of course possible to employ partial vacuum evaporation or the combination of partial vacuum evaporation and heat, or any other prior art evaporation technique.

It is obvious that, instead of the evaporation principle, the installation 15 - 19 may operate e.g. on the principle of the reverse osmosis, or it is possible to provide the distillation funnel with an overflow pipe and feed concentrated liquid manually via the valve 19 or from the container or to employ some other prior art method for controlling the concentration.

Figure 4 shows an example of controlling the temperatures. When the temperature of the outdoor air is near the desired inlet air temperature, whereby a full heat recovery capacity of the circuit 1 - 7 is not required, the exhaust air flow B-B' may be e.g. directed entirely or partly past the humidification chamber 2 by opening a damper 25 and closing a damper 26. The operation of the dampers may of course be periodic, as well. It is also possible to adjust the liquid flow in the circuit 1 - 7 e.g. by adjusting the rotating speed of the pump 4, to adjust the flow by means of a throttle valve placed in the circuit 1 - 7, to provide the inlet air exchanger 1 with by-pass adjustment

according to the principle of Figure 4, to arrange between pipes 5 and 6 a by-pass of the exchanger 1 or the humidifier 7 by means of a valve or a circulation pipe or to employ some other prior art adjustment method or a combination thereof.

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If the heating or cooling power recovered from the exhaust air is not sufficient, it is possible to supply the circuit 1 - 7 with additional power e.g. in accordance with Figure 4 by means of a heat exchanger 20. In Figure 4, the exchanger 20 has a circulating pump 22 of its own, and bypass adjustment arranged by means of a valve 23 between an inlet pipe 21 and an exhaust pipe 24 for adjusting the temperature. Of course, the additional power may be supplied e.g. to a separate heat exchanger/exchangers placed in the inlet duct 9 after the exchanger 1, likewise the adjustment of the circuit 1 - 7 may be arranged by means of a bypass of the exchanger 20, by adjusting the rotating speed of the pump etc. All these prior art arrangements of course fall within the scope of the invention.

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The embodiments disclosed above are by no means intended to limit the invention, but the invention may be modified completely freely within the scope of the attached claims. It is thus obvious that the arrangement of the invention or its details do not necessarily have to be exactly similar to those shown in the figures, but the invention also allows solutions of other kinds.

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## Claims

1. A method for conveying heat, in which heating or cooling capacity is conveyed from the exhaust air (B-B') of ventilation or air conditioning of standard rooms into inlet air (A-A') by means of an inlet air heat exchanger, via which non-freezing heat transfer liquid is circulated,  
c h a r a c t e r i z e d in that the non-freezing heat transfer liquid is brought into direct contact with the exhaust air (B-B').
2. A method as claimed in claim 1,  
c h a r a c t e r i z e d in that the heat transfer liquid and the exhaust air (B-B') are arranged to flow in the opposite directions in a contact situation.
3. A method as claimed in claim 1 or 2,  
c h a r a c t e r i z e d in that the heat transfer liquid and the exhaust air (B-B') are arranged to flow substantially in the vertical direction.
4. A method as claimed in any one of the preceding claims, c h a r a c t e r i z e d in that the exhaust air (B-B') and/or the heat transfer liquid are filtered.
5. A method as claimed in any one of the preceding claims, c h a r a c t e r i z e d in that the heat transfer liquid is formed from a compound of two or more components.
6. A method as claimed in claim 5,  
c h a r a c t e r i z e d in that the concentration of the heat transfer liquid is measured and adjusted.
7. A method as claimed in claim 6,  
c h a r a c t e r i z e d in that the concentration of the heat transfer liquid is changed upon the outdoor air temperature changing.
8. A method as claimed in any one of the

preceding claims 5 - 7, characterized in that the heat transfer liquid is replaced when the outdoor air temperature has risen so high that the risk of freezing is eliminated, and replaced again upon the temperature dropping so low that the risk of freezing exists.

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9. An arrangement for conveying heat, wherein heating or cooling capacity is arranged to be conveyed from the exhaust air (B-B') of ventilation or air conditioning of standard rooms into inlet air (A-A') by means of a heat exchanger, via which non-freezing heat transfer liquid is arranged to circulate, characterized by comprising means (3, 7) that are arranged to bring the heat transfer liquid into direct contact with the exhaust air (B-B').

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10. An arrangement as claimed in claim 9, characterized in that the means (3) comprise spraying nozzles via which the heat transfer liquid is arranged to flow.

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11. An arrangement as claimed in claim 9, characterized in that means (7) comprise a humidification cell.

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12. An arrangement as claimed in any one of the preceding claims 9 - 11, characterized by comprising filter means (10, 12) that are arranged to filter the exhaust air (B-B') and/or the heat transfer liquid.

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13. An arrangement as claimed in any one of the preceding claims 9 - 12, characterized in that the heat transfer liquid is a compound of two or more components.

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14. An arrangement as claimed in claim 13, characterized by comprising measurement and adjustment means (13, 14, 15-19) for measuring and adjusting the concentration of the heat transfer liquid.

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15. An arrangement as claimed in claim 14,  
c h a r a c t e r i z e d in that the measurement and  
adjustment means (13, 14, 15-19) are arranged to change  
the concentration of the heat transfer liquid upon the  
outdoor air temperature changing.

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16. An arrangement as claimed in any one of  
the preceding claims 13 - 15,  
c h a r a c t e r i z e d by comprising means for  
replacing the heat transfer liquid after the outdoor  
air temperature rising so high that the risk of  
freezing is eliminated and replacing the heat transfer  
liquid again upon the outdoor air temperature dropping  
so low that the risk of freezing exists.

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17. An arrangement as claimed in any one of  
the preceding claims 13 - 16,  
c h a r a c t e r i z e d in that the measurement and  
adjustment means (13, 14, 15-19) and the means for  
replacing the heat transfer liquid are manually  
operated.

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18. An arrangement as claimed in any one of  
the preceding claims 13 - 16,  
c h a r a c t e r i z e d in that the measurement and  
adjustment means (13, 14, 15-19) and the means for  
replacing the heat transfer liquid are automatic  
devices.

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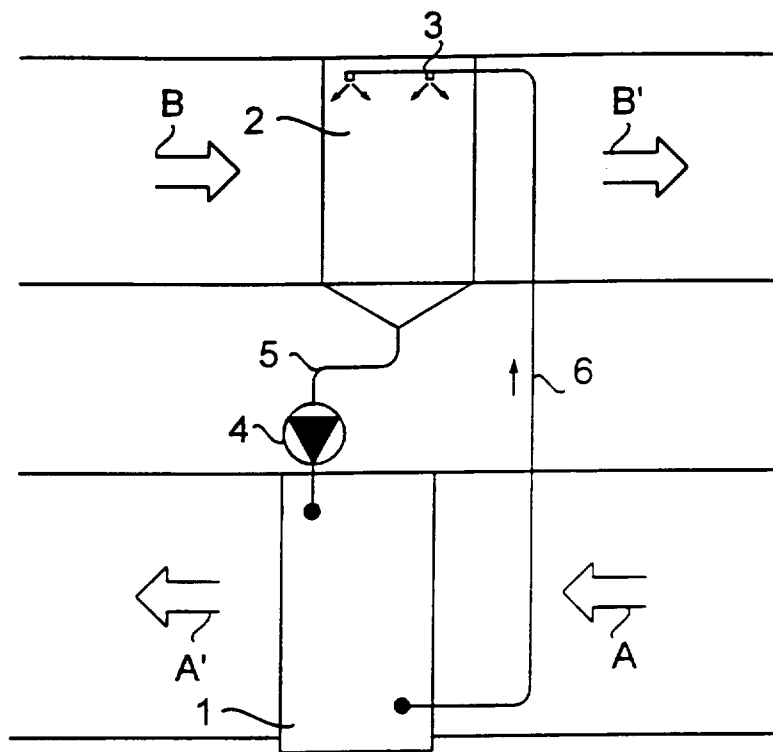


FIG. 1

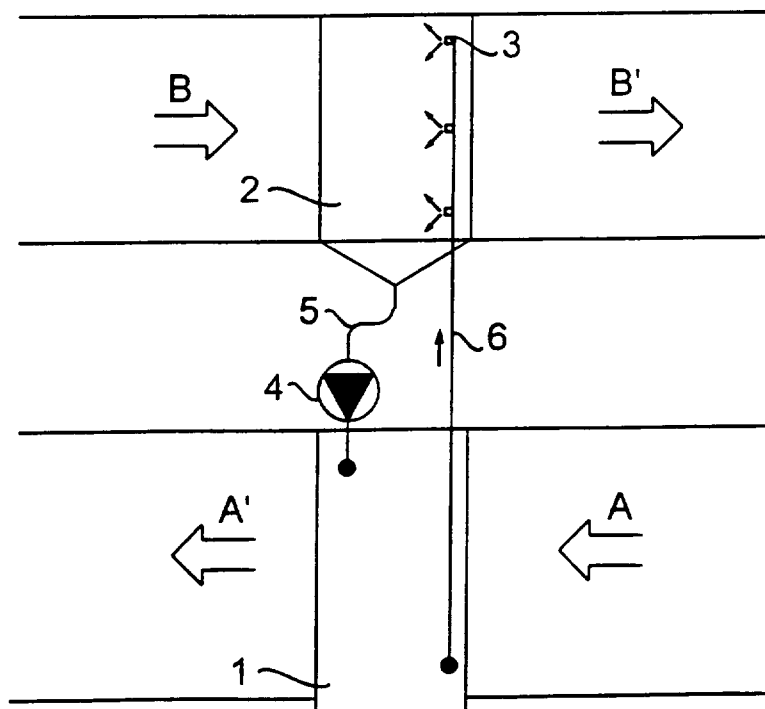


FIG. 2



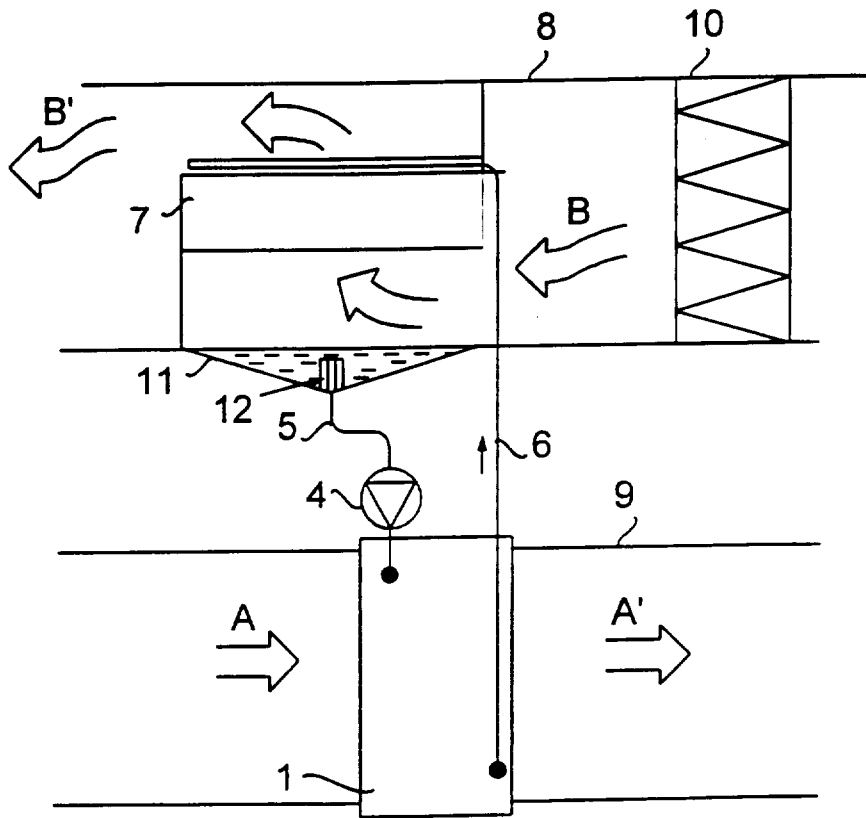


FIG. 3



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 96/00564

A. CLASSIFICATION OF SUBJECT MATTER		
IPC6: F24F 12/00, F28C 3/06 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
IPC6: F24F, F28C		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
SE,DK,FI,NO classes as above		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 9504902 A1 (OY KOLSTER AB), 16 February 1995 (16.02.95) --	1-5,9-13
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<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
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Date of the actual completion of the international search		Date of mailing of the international search report
5 February 1997		06.02.1997
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86		Authorized officer  Helene Eliasson Telephone No. +46 8 782 25 00

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 96/00564

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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**INTERNATIONAL SEARCH REPORT**  
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GB-A- 2129118	10/05/84	NONE	
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