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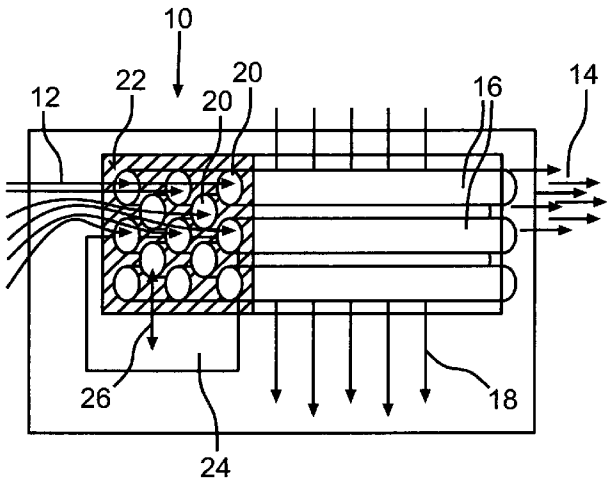
(54) **Title:** DEVICE FOR HUMIDIFYING A GAS

Fig. 1



(57) **Abstract:** In a gas-to-gas humidifier (10) the active membrane surface area, by way of which waste gas supplied to the gas-to-gas humidifier releases moisture to air to be humidified, is controlled. This is possible in particular continuously by using a slide (24), which covers a portion of the inlets (20) of the passages (16). By the position of the slide (24), the humidity level of the air to be humidified by the gas-to-gas humidifier (10) may be defined. Owing to the use of a slide (24) or another mechanical adjusting element, which directly covers inlets (20) or outlets of passages, the gas-to-gas humidifier (10) is of particularly compact construction and thus takes up only a small amount of space, at the same time being inexpensive.

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DEVICE FOR HUMIDIFYING A GAS

The invention relates to a device for humidifying a gas according to the preamble of patent claim 1. Under the short name "humidifiers", such devices are also known from fuel cell systems in which hydrogen reacts with atmospheric oxygen to yield water. In such cases, said reaction is promoted if at least the supplied air has a particular humidity level.

A distinction is drawn between "contact humidifiers", in which liquid water is injected from a reservoir, and gas-to-gas humidifiers, in which the waste gas of the fuel cell system, which contains water anyway, is used as a source of moisture, the waste gas being conveyed past membranes through which the moisture may pass in order to reach the gas to be humidified. Contact humidifiers have the disadvantage that they may ice up particularly quickly at cold ambient temperatures, if they are not expensively insulated or specially heated. However, contact humidifiers have the advantage that the quantity of moisture supplied may be controlled relatively precisely. In the case of gas-to-gas humidifiers, on the other hand, control or regulation of the humidity level is difficult. The temperatures of the gas streams vary depending on ambient conditions and load, and this has a direct effect on humidifying efficiency, without it being possible to intervene with regard to control. The moisture content of the waste gas varies as a function of load. Feedback effects may then occur: the more water is discharged from the fuel cell stack, the more water is transferred in the humidifier from the outgoing air stream to the incoming air stream.

In addition, conventional gas-to-gas humidifiers are constructed in such a way that the surface area of the membrane, via which moisture exchange proceeds, is as large as possible. To this end, the device for humidifying a gas regularly comprises a plurality of

passages, through which gas may pass. In gas-to-gas humidifiers, there are provided both passages for the moisture-receiving gas - in the passages the through-flowing gas thus receives moisture from another medium during operation - and passages through which the moisture-releasing gas is passed. Conventionally, the inlets and outlets of the passages are precisely defined. It is assumed here that a majority of the inlets and preferably all of the inlets are formed in a common surface. It is also possible for a majority of the outlets, preferably all of the outlets, to be formed in a common surface. It is not impossible for both the passage inlets and outlets to be formed in a common surface, these then preferably being inlets and outlets of different passages.

The provision of a plurality of passages makes it difficult to control the level of humidity in the air passing through. The active membrane surface area is firstly predetermined per se by the number of passages. This structure means that the pressure drops over the device for humidifying a gas vary with the through-flowing air volume (which corresponds to the load of the fuel cell system), and these pressure drops likewise influence the moisture level which the gas to be humidified attains.

It is known from DE 101 02 447 A1 to divide a device for humidifying a gas into a plurality of sub-devices, namely either to provide three hollow fiber membrane modules or to divide one hollow fiber membrane module into three. A valve is associated with each unit, said valve determining whether or not the unit is connected. In the case of three such units, a third of the humidifier may then optionally actively be used, or two thirds of the humidifier or the entire humidifier.

Since in DE 101 02 447 A1 each of the stated units has to be provided with its own valve, both on the dry air feed side and on the waste gas feed side, the structure of the humidifier is very complex. Valves may also ice up rapidly at cold ambient temperatures and overall are susceptible to failure. They take up space and installation thereof takes time. The humidifier from DE 101 02 447 A1 may be used in three stages, whereby the moisture content may be only very roughly regulated.

It is the object of the invention further to develop a device for humidifying a gas according to the preamble of patent claim 1 in such a way that the above-stated disadvantages are avoided, i.e. the device is inexpensive, takes up only a small amount of installation space

and also weight, and exhibits as little susceptibility to failure as possible, in particular as far as operation at low temperatures is concerned.

The object is achieved by a device for humidifying a gas having the features of patent claim 1. According to the invention, a mechanical adjusting element is thus provided, which may be brought into at least two positions, with it directly covering at least one portion of the surface (in which the inlets/outlets are formed) in at least one of the positions, so at least partly closing some of the inlets and/or outlets.

The invention thus abandons the use of valves arranged outside the humidifier. Instead, a simple adjusting element is used, which is associated directly with the passages and thus with the active membranes. This direct association gives rise to a compact structure, which is associated with weight and space savings and at the same time is cheaper than using valves. The direct association of the mechanical adjusting element with the surface with the inlets or outlets makes possible in particular continuous adjustment of the active membrane surface area, namely by making the mechanical adjusting element continuously displaceable, at least between two end positions, such that the size of a subarea of the surface covered by the mechanical adjusting element is adjustable in any desired way between two extreme values. If inlets or outlets are distributed over the surface in such a way that the number of covered inlets or outlets is defined by displacement of the adjusting element, the mechanical adjusting element directly influences as a result of its position the number of passages into which gas may enter and thus the number of membranes in the walls of the passages via which humidification takes place.

At its simplest, the continuous displacement may be such that a planar surface is selected as the surface and a plate-shaped slide is selected as the mechanical adjusting element. In the case of a planar surface, the mechanical adjusting element may alternatively take the form of a diaphragm, in particular of a diaphragm constructed of lamellae like in a camera.

It is also possible that the surface into which the passages open with their inlets or outlets is the inner surface of a recess, the air then being guided for example into the recess and then outwards over the surface, if the inlets are formed in the surface. If the recess is a cylindrical recess, the air may be guided radially outwards. The mechanical adjusting

element may then be a body which fits perfectly into the recess, such that it partially covers the surface when inserted into the recess. It makes good sense for the mechanical adjusting element to take the form of a tubular body, through which the air passes in a straight line, in particular into that area of the recess into which the mechanical adjusting element has not yet been inserted.

To regulate the moisture supplied to the gas, it is not absolutely necessary for the mechanical adjusting element to operate continuously. It is also wholly possible for the mechanical adjusting element to be such that the proportion of the surface which is covered may be defined in relatively small stages. This is possible in particular when the mechanical adjusting element comprises a plurality of sub-elements, the surface then being covered sub-element by sub-element. In a particularly simple embodiment thereof the mechanical adjusting element takes the form of a roller blind.

As already mentioned above, the present invention is particularly suitable for use in a gas-to-gas humidifier. In principle, it is possible, in the case of a gas-to-gas humidifier, to regulate the active membrane surface area by way of the number of covered inlets or outlets to the passages to which the waste gas, which releases the moisture, is conveyed, but preferably the mechanical adjusting element is used to regulate the dry air supplied, i.e. that gas which has to be humidified.

The invention also finds expression in a fuel cell system having a device according to the invention for humidifying a gas.

The device according to the invention also makes possible in particular regulation of the humidity of the gas, in particular the air supplied to a fuel cell stack, such that a preferred embodiment of the fuel cell system also comprises a regulating means. This operates as a function of a controlled variable, which is preferably a measure of the load of the fuel cell stack. The controlled variable may here be the quantity of waste gas or indeed the quantity of air which passes or is intended to pass through the device for humidifying a gas.

The principal application of a fuel cell system having a device according to the invention for humidifying a gas is to provide power for driving an electric motor of a motor vehicle.

A preferred embodiment of the invention is described below with reference to the drawing, the figure being a schematic simplification illustrating the structure of a gas-to-gas humidifier according to the invention.

A gas-to-gas humidifier designated overall as 10 serves to humidify air flowing in from the left-hand side in the figure (cf. arrows 12) and flowing out on the right-hand side in the figure (cf. arrows 14). The air is passed through a plurality of passages 16, whose walls are water-permeable, taking the form in particular of membranes. Moist air is conveyed past the membranes. This is illustrated in the figure by the arrows 18, without the precise flow path of this air being illustrated. In a fuel cell system, the already moist air is in particular the waste gas of the fuel cell stack, in which hydrogen reacts with atmospheric oxygen to yield water. The water from the waste gas is then sensibly used to humidify the air supplied to the fuel cell stack, in order to promote the reaction in the fuel cell stack. In the exemplary embodiment illustrated in the figure, the passages 16 comprise inlets 20, which are formed in a planar surface 22.

The gas-to-gas humidifier 10 then comprises a mechanical adjusting element, namely a slide 24, which is plate-shaped and may be pushed precisely over the surface 22 and away again, cf. the double-headed arrow 26.

When the slide 24 is pushed in front of the surface 22, it covers some of the inlets 20. The inlets 20 are distributed in such a way that the number of inlets 20 covered by the mechanical adjusting element 24 increases, the further the slide 24 is pushed upwards in the figure. No more air is able to flow through the passages 16 whose inlets 20 have been covered by the mechanical adjusting element 24, and all the air flows through the passages 16 whose inlets 20 have not been covered. Some inlets 20 may be partially covered, but the proportion thereof is negligible in a real system, in which the number of passages 16 is greater by several orders of magnitude than in the figure.

The active membrane surface area by way of which the waste gas may release moisture to the air is proportional to the number of passages 16. By varying the active membrane surface area, it is particularly simple to influence the moisture content of the air flowing out of the gas-to-gas humidifier 10 in accordance with the arrows 14. The invention enables precise regulation of the moisture content of the air, e.g. as a function of the load of a fuel cell stack, of which the amount of air supplied, which could be measured for

example directly in the humidifier 10 itself, may be a measure, or of which the amount of waste gas may also be a measure, which could likewise be measured in the humidifier 10. The correcting variable is then advance of the slide 24 in accordance with the double-headed arrow 26, an electric motor conventionally being activated by an electronic regulating unit in order in practice to implement regulation.

Instead of on the inlet side of the passage 16, the mechanical adjusting element 24 may also be arranged on the outlet side thereof. It is not even necessary for the slide 24 to cover in- or outlets for the dry air: rather, it is also possible variably to cover corresponding inlets or outlets, not shown in the figure, for the waste gas by a mechanical adjusting element.

List of reference signs

10	Gas-to-gas humidifier
12,14,26	Arrows indicating direction
16	Passages
20	Inlets
22	Surface
24	Adjusting element

Patent Claims

1. A device (10) for humidifying a gas, having a plurality of passages (16), through which gas may be passed and from which the gas flowing through during operation receives moisture from another medium or releases moisture to another medium, all the passages (16) having an inlet (20) and an outlet and a majority of the inlets (20) and/or a majority of the outlets being formed in a common surface (22), characterized by a mechanical adjusting element (24), which may be brought into at least two positions, with it directly covering at least one portion of the surface (22) in at least one of the positions, so at least partly closing at least some of the inlets (20) and/or outlets.

2. The device (10) as claimed in claim 1, characterized in that the mechanical adjusting element (24) is continuously displaceable, such that the size of a covered subarea of the surface (22) is adjustable continuously between two extreme values.

3. The device (10) as claimed in claim 2, characterized in that the surface (22) is planar and the mechanical adjusting element is a plate-shaped slide (24).

4. The device (10) as claimed in claim 2, characterized in that the surface is the inner surface of a recess and the mechanical adjusting element is a body, preferably a tubular body, which may be slid into the recess.

5. The device as claimed in claim 1, characterized in that the mechanical adjusting element comprises a plurality of sub-elements and the surface may be covered sub-element by sub-element.

6. The device as claimed in claim 5, characterized in that the mechanical adjusting element is a roller blind.

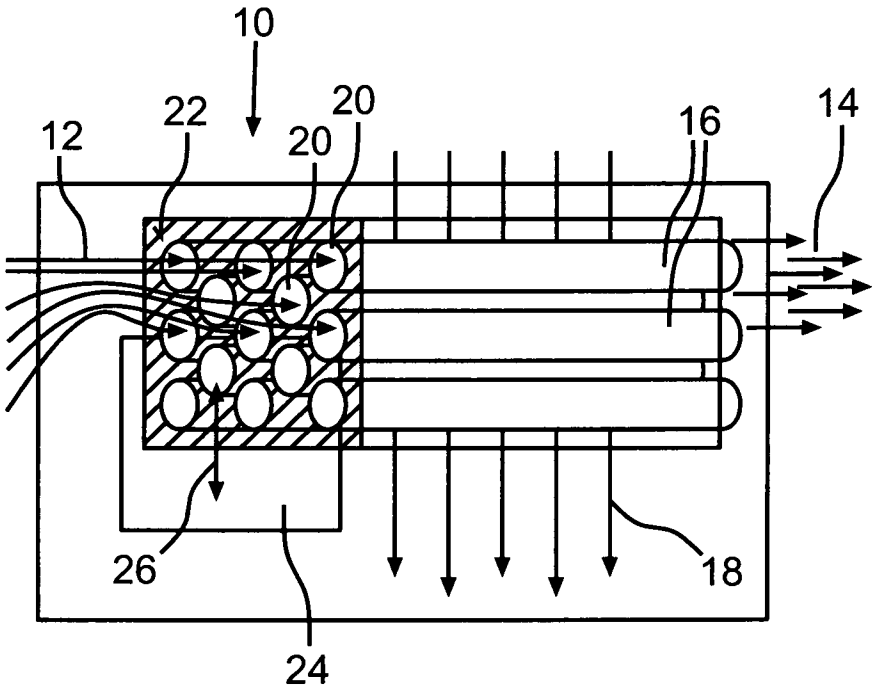
7. The device as claimed in one of the preceding claims, characterized in that it is a gas-to-gas humidifier (10), and the plurality of passages, whose inlets (20) and/or outlets are formed in the surface (22), serve for passage of that gas which requires humidification.

8. A fuel cell system having a device (10) as claimed in one of the preceding claims.

9. The fuel cell system as claimed in claim 8, having a regulating device which regulates the humidity of the gas.

10. A motor vehicle having a fuel cell system as claimed in claim 8 or 9.

Fig. 1



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/009589

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M8/04

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)
H01M F24F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 801 385 A (SACHTLER JUERGEN [DE] ET AL) 31 January 1989 (1989-01-31) column 3, line 39 - column 5, line 19 figures 1-4	1-10
A	DE 101 02 447 A1 (HONDA MOTOR CO LTD [JP]) 13 September 2001 (2001-09-13) cited in the application abstract figures 1-5 page 5, line 20 - page 7, line 44	1-10
P,X	WO 2008/121618 A (BALLARD POWER SYSTEMS [CA]; BALLARD MATERIAL PRODUCTS INC [US]; GALLAG) 9 October 2008 (2008-10-09) abstract page 4, line 4 - page 5, line 22 page 9, line 18 - page 12, line 17 figures 3a-c,4a-c	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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