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Description

[0001] The invention relates to a fuel cell system for a fuel cell stack. The invention relates not so much to the fuel cell stack as to the further components of a fuel cell system for supplying media and setting the operating parameters for a fuel cell stack, such as in particular the housing and the media supply with air and hydrogen and the control thereof.

[0002] Typical components of a fuel cell system are a fuel cell stack, which comprises the actual fuel cell in the form of a plurality of individual cells, each with a cathode and an anode and an electrolyte arranged therebetween, for example in the form of a membrane, and a housing. The housing accommodates the necessary components, e.g. air ducts and hydrogen line, which are required to supply the necessary hydrogen to the anodes of the fuel cell stack and the necessary oxygen to the cathodes of the fuel cell stack, for example as part of supplied ambient air. Furthermore, the fuel cell system comprises means for controlling the respective supplied volume flow of hydrogen and air as well as for temperature and humidity management, since released reaction heat and generated water have to be removed. In the case of the fuel cell, it is important to maintain an advantageous operating temperature for as long as possible.

[0003] In this context, the invention relates in particular to a fuel cell system having a fuel cell stack with an open cathode, in which the anodes to be supplied with hydrogen are connected to channels for the central supply of hydrogen, while the cathodes to be supplied with oxygen are quasi freely accessible and are arranged next to one another in layers, so that the oxygen supply must come from the side of the housing of the fuel cell system. The water resulting from the reaction of oxygen and hydrogen on the cathode side must be removed as moisture. Fuel cell stacks with an open cathode are known in principle.

[0004] The invention is based on the task of creating a fuel cell system for a fuel cell stack with an open cathode, which allows the simplest and most efficient operation possible.

[0005] According to the invention, this task is solved by a fuel cell system which

-has at least two fans or compressors arranged one behind the other in the direction of air flow in the supply air or exhaust air duct, preferably in the form of axial fans or diagonal fans and preferably with different outputs.

-a U-shaped air duct with supply air and exhaust air ducts having an inlet and outlet opening, respectively, on the same side of the housing of the fuel cell system, so that air is guided from this side of the housing by means of a supply air duct to the chamber for the fuel cell stack and from there via an exhaust air duct back to the same side of the housing;

-a housing which, in addition to a chamber for a fuel cell stack and a supply air duct and an exhaust air duct, has two further, separate housing compartments, namely a housing compartment for accommodating a preferably electronic controller and a second housing compartment for accommodating all the components which serve to supply and, if appropriate, remove hydrogen to the fuel cell stack; and a bypass air duct between a supply air duct for supplying ambient air to a chamber for a fuel cell stack and an exhaust air duct for removing air from the chamber for the fuel cell stack.

-a chamber for receiving a fuel cell stack, the chamber being configured such that the fuel cell stack is angled relative to the housing and the chamber; and

-a closed, especially heat-insulating housing.

[0006] The invention is defined by the appended claims.

[0007] Figure 5 shows an embodiment of the invention. Figures 1-4 and 6-10 show additional optional

Details and embodiments. Of these shows:

Fig. 1: A schematic sectional view through a preferred fuel cell system;

Fig. 2: an illustration similar to Fig. 1 to illustrate further housing compartments of the fuel cell system of Fig. 1;

Fig. 3a to 3c: a fuel cell system similar to Fig. 1 with an additional bypass air duct;

Fig. 4a and 4b:A modular fuel cell system in more detail;

Fig. 5: A schematic diagram illustrating the use of multiple fans in the supply and/or exhaust duct for an air supply to a fuel cell stack according to the invention.

Fig. 6: a fuel cell stack with open cathode and ventilation hoods attached; Fig. 7: an advantageous arrangement of the fuel cell stack and ventilation hoods;

Fig. 8: A particularly preferred variant of a chamber for a fuel cell stack;

Fig. 9: a schematic illustration of the relative arrangement of a supply air duct and an exhaust air duct relative to a chamber for a fuel cell stack; and

Fig. 10: A schematic diagram of a preferred relative arrangement of a chamber for a fuel cell stack and other housing compartments for a fuel cell system controller and for hydrogen supply components.

[0008] Fig. 1 shows in schematic view a horizontal section through a fuel cell system 10 with a chamber 12 for a fuel cell stack 14 as well as a supply air duct 16 to the chamber 12 and an exhaust air duct 18 from the chamber 12. A deflection duct 17 is arranged between the supply air duct 16 and the chamber 12, with which the air flowing in via the supply air duct 16 is deflected by 180° in a U-shape. In addition, a compressor or fan 20 is schematically shown in the supply air duct 16. These components are enclosed by a schematically shown housing 22.

[0009] The supply air duct 16, the recirculation duct 17, the exhaust air duct 18, the chamber 12, and the fan 20 can be formed as independent modules that are interchangeable and can be combined with each other as desired.

[0010] Fig. 1 illustrates a fuel cell system in which the supply air duct 16 and the exhaust air duct 18 each open out on the same side (in the figure, the left side) of the housing

22. This results in an advantageous U-shaped air flow, which allows the fuel cell system to be arranged practically anywhere in a room, whereby both the supply air duct and the exhaust air duct can optionally open out into the open air or into the interior of the room. Accordingly, the fuel cell system can be arranged in the room.

[0011] Fig. 2 shows a fuel cell system 10' similar to that shown in Fig. 1, wherein, firstly, the fan 20 is shown in the form of an axial fan 20'. In addition, Fig. 2 shows that the housing 22' has its own housing compartment 24 for accommodating control components, i.e. specifically for accommodating control electronics, as well as a further, third housing compartment 26 for accommodating the components for the hydrogen supply. As can already be seen from Fig. 2, the third housing compartment 26 for accommodating the components for hydrogen supply preferably has a hydrogen connection 28 which is not arranged on the same housing side as the mouths of the supply air duct 16 and the exhaust air duct 18, but on another, preferably opposite housing side. A connection terminal 30 is provided on the side of the chamber 12 for the fuel cell stack 14, via which the fuel cell stack 14 is to be connected to the components for the hydrogen supply (not shown in Fig. 2) in the third housing compartment 26, so that the required hydrogen can be supplied to the fuel cell stack 14 via the connection terminal 30. The provision of separate housing compartments for control components and for hydrogen supply components represents a second idea of the invention which can also be implemented independently.

[0012] Finally, Figures 3a to 3c illustrate another embodiment comprising a bypass air duct 32 connecting the supply air duct 16 to the exhaust air duct 18. As can also be seen from the three figures, a supply air damper 34 is arranged in the supply air duct 16, an exhaust air damper 36 is arranged in the exhaust air duct 18, and a recirculation air damper 38 is arranged in the bypass air duct 32. By supply air damper, exhaust air damper and recirculation air damper, in the sense of the present, is meant any device with which the hydraulic diameter of the supply air duct, exhaust air duct or bypass duct, respectively, can be changed in a controlled manner, e.g., also an iris diaphragm or a slide valve.

[0013] The bypass duct 32 as well as the supply air damper 34 and the exhaust air damper 36 may also be designed as interchangeable modules that can be combined in any desired manner, resulting in an overall modular design of the fuel cell system.

[0014] Fig. 3a shows an operating condition in which the supply air damper 34 and the exhaust air damper 36 are fully open and the recirculation air damper 38 is fully closed, so that the bypass air duct 32 is de facto ineffective and the fuel system behaves like a conventional fuel cell system.

[0015] At cold ambient temperatures, for example at ambient temperatures of less than 10°C, the supply air damper 34 and the exhaust air damper 36 can be closed and the recirculation air damper 38 can be opened to start the fuel cell system 10, so that de facto no ambient air is drawn into the supply air duct 16, but rather air circulates through the supply air duct 16, the chamber 12 for the fuel cell stack 14, the exhaust air duct 18 and the bypass air duct 32. In this way, the heat generated in the fuel cell stack 14 can be effectively utilized and the fuel cell system 10 can be brought to an advantageous operating temperature of, for example, 50°C to 60°C as quickly as possible. This is illustrated in Fig. 3b.

[0016] As shown in Fig. 3c, partial recirculation of air passing through the chamber 12 can also be accomplished by having the supply air damper 34 and the exhaust air damper 36 only partially open and closed, respectively, while the recirculation air damper 28 is open.

[0017] A fuel cell system 10 having a bypass air duct 32 opens the following possible modes of operation:

For example, the air may be recirculated through the system multiple times, e.g., ten times, until the fuel cell stack 14 reaches an acceptable temperature of, for example, at least 20°C. Here, as shown in Fig. 3b, the supply air damper 34 and the exhaust air damper 36 are closed and the recirculation air damper 38 is open. When a fuel cell stack temperature of about 20°C is reached, the supply air damper 34 and the exhaust air damper 36 can again be fully or partially opened to supply ambient air to the fuel cell stack partially or fully.

[0018] Instead of completely closing the supply air flap 34 and the exhaust air flap 36 when the fuel cell system is started, as shown in Fig. 3b, the supply air flap 34 and the exhaust air flap 36 can also be partially closed and open, respectively, as shown in Fig. 3c.

[0019] With reference to Figs. 3a to 3c, it should be noted that in the case of a bypass air duct 32, a required fan 32 is to be arranged downstream of the opening of the bypass air duct into the supply air duct 16 and/or upstream of the opening of the bypass air duct 32 into the exhaust air duct 18 in the direction of flow, so that the fan can also be effective in the operating mode illustrated in Fig. 3b.

[0020] Figures 4a and 4b show exemplary modular fuel cell systems in more detail.

[0021] According to the preferred embodiment of the chamber 12 shown in Figures 4a and 4b, the chamber 12 is formed by two shells 12.1 and 12. 2. This facilitates assembly. With the upper shell (shell 12.1) removed, all components are easily accessible. The lower shell 12.2 contains an opening and a surrounding frame 42 with sealing surface 44. This frame forms a support 42 for the fuel cell stack 14, which closes the opening as soon as it is placed on it. The shell 12.1 includes pressing contours 52 that press on the fuel cell stack 14 and press it onto the sealing surface 44 of the lower shell 12.2 once the chamber 12 is closed.

[0022] Ideally, both the support surface 42 and the contact pressure contours 52 precisely match the geometry of the fuel cell stack. Fixation of the fuel cell stack in the chamber is thus achieved by positive locking as soon as the chamber is closed, and no separate elements are required for fixing the fuel cell stack.

[0023] The inclined position of the fuel cell stack divides the chamber 12 to form two spaces, which are sealed from each other by insertion of the fuel cell stack. The support 42 for the fuel cell stack is also the sealing surface. The chamber 12 itself no longer needs to be completely sealed to the outside. Air entering the first interstitial space can only enter the interstitial space by flowing through the fuel cell stack 14. Short-circuit flow past the fuel cell stack is thus not possible.

[0024] Due to the inclined position of the fuel cell stack, a very low overall height of the arrangement is achieved with simultaneous optimum air distribution. The fuel cell stack acts like a "partition wall" and forms the tapering first intermediate space 50.1 on the air inlet side and the widening second intermediate space 50.2 on the air outlet side in the closed chamber 12. Due to this arrangement, the fuel cell stack itself is optimally flowed through and there is no air accumulation in the interspaces.

[0025] The chamber concept is easily adaptable to different stack sizes of the same type. Only one dimension has to be changed, which can be realized by appropriately designed intermediate parts on the chamber walls.

[0026] The chamber concept realizes a part of the preferred modularity in that an air filter 54 or the fan 20" are easily exchangeable. of the invention, several compressors, for example in the form of axial compressors, are arranged in series (cascaded) in the air circuit - instead of the usual one compressor. For example, two compressors 20.1 and 20.2 can be arranged in series in the supply air duct, or two compressors 20.3 and 20.4 can be arranged in series in the exhaust air duct. Likewise, a first compressor 20.1 can be arranged in the supply air duct and a second compressor 20.4 in the exhaust air duct. Fig. 4 shows an embodiment example with a total of four compressors 20.1 to 20.4, two of which are arranged in the supply air duct 16 and two in the exhaust air duct 18. A fuel cell stack 14' is shown schematically between supply air duct 16 and exhaust air duct 18. If the compressors are each designed as a separate module, they can be combined with each other as desired and thus optimally adapted to different operating conditions or different fuel cell stacks.

[0027] The compressors 20.1 to 20.4 are preferably axial fans and also preferably have different nominal or maximum capacities.

[0028] By using multiple compressors or fans instead of the usual one compressor or fan, the following problems typically encountered when using only one fan can be avoided:

-The minimum starting volume flow of the compressor is too high,

-the maximum volume flow of the compressor is not sufficient at high ambient temperatures, for example of more than 35°C, and

-additional pressure losses due to the integration of additional piping after installation of the fuel cell system at the customer's site negatively affect the compressor performance and cannot be easily compensated by a single compressor.

[0029] When using two compressors, the problem of minimum startup volume flow can be solved by operating only one of the two fans when the air demand is low in the partial load range of the fuel cell system. When axial fans are used, an overall higher pressure difference between inlet and outlet can be generated because the two axial fans are connected in series, increasing the pressure capacity of the overall compressor. Alternatively, two compressors can be arranged in parallel to increase the volume flow. In this way, by arranging the compressors appropriately or by switching them on and off selectively, the required fan power can be realized in a more efficient manner than would be possible with a single fan, which might have to be operated - for example in partial load operation - with reduced efficiency. In this way, the overall efficiency of the fuel cell system can also be increased. Overall, any power points can thus be effortlessly controlled by individual control of the compressors.

[0030] A further inventive idea may also contribute to this, which is not shown pictorially in the figures and which consists in the fact that an air flap, which is spring-loaded in one operating state and acts as a pressure reducer, is associated with the fan or compressor in order to optimize the operating point of the compressor or fan in the partial load range, wherein the air flap can be opened at full load so that it then does not act as a pressure reducer.

[0031] If, as shown in Fig. 5, at least one compressor is arranged in the supply air duct 16 in a pressurizing manner and the other compressor is arranged in the exhaust air duct 18 in a suction manner, so that one compressor is arranged on the pressure side and the other compressor is arranged on the suction side, there is also an improvement in the uniform distribution of the flow over the fuel cell stack 14. Overall, there are the advantages that the volumetric flow and the pressure of the supply are easily scalable. In addition, a simple design with a small size results, since axial fans that would otherwise be rather awkward can also be used. Finally, the uniform distribution of the air flow over the stack can also be improved.

[0032] Arbitrarily, the arrangement of the fuel cell stack 14 in the chamber 12 or housing 22 may be optimized.

[0033] In currently known fuel cell systems having an open cathode fuel cell stack, ventilation hoods 40.1 and 40.2 are typically provided as shown in connection with a stack 14 in Fig. 6. Air is supplied to a first vent hood 40.1 and introduced into the stack 14 through the vent hood 40.1, and flows past the open cathodes through the stack to the second vent hood 40.2.

[0034] In order to achieve optimized housing dimensions that allow an overall small outer housing and thus also lead to overall lower heat losses through the housing wall, the stack 14 can be arranged at an angle, as shown in Fig. 7. In this case, the outer sides of the ventilation hoods 40.1 and 40.2 preferably run parallel to an outer wall, for example an upper side or lower side of the housing 20 of the fuel cell system 10 .

[0035] Fig. 7 further shows a "radial fan 20" as a compressor connected to the supply air hood 40.1.

[0036] Finally, Fig. 8 shows a particularly optimized variant of the arrangement of a fuel cell stack 14 in a dedicated chamber 12 of the housing 22. Here, the chamber 12 is oriented such that its chamber walls 12.1 and 12.2 are approximately parallel to outer walls of the housing 22. The fuel cell stack 14 is arranged at an angle in the chamber 12. As can be seen from Fig. 7, a supply air duct 16 and the exhaust air duct 18 also adjoin the chamber 12 in such a way that, in plan view (Fig. 7 represents a vertical section), an arrangement of supply air duct 16, chamber 12 for the fuel cell stack 14 and exhaust air duct 18 results as shown schematically in Fig. 9. The U-shaped air duct already explained with reference to Figs. 1 and 2 can be seen.

[0037] Finally, Fig. 10 illustrates yet another embodiment consisting of dividing the housing 22 into at least three housing compartments, one housing compartment comprising the chamber 12 and air ducts 16 and 18, and a separate housing compartment 24 containing control components, and finally a third housing compartment 26 containing the hydrogen supply components.

[0038] If all embodiments are realized in a fuel cell system, the result is a fuel cell system that has a compact housing with small dimensions. This preferably consists of a thermally insulating material to further reduce heat losses.

[0039] The invention contributes to a fuel cell system that has high efficiency even in partial load conditions and can be quickly brought to the optimum operating temperature even at low ambient temperatures.

## Patentkrav

**1.** Brændselscellesystem (10) med et hus (22) med et kammer (12) til optagelse af en brændselscellestak (14) samt med en tilførselsluftkanal (16) til tilførsel af omgivelsesluft til kammeret (12) og en afgangsluftkanal (18) til bortledning af luft fra kammeret (12) til omgivelserne, **kendetegnet ved, at** brændselscellesystemet (10) omfatter mindst to ventilatorer (20) eller kompressorer, der er anbragt efter hinanden i luftens strømningsretning i tilførselsluft- og/eller afgangsluftkanalen (18).

**2.** Brændselscellesystem (10) ifølge krav 1, **kendetegnet ved, at** ventilatorerne (20) er aksialventilatorer (20') eller diagonalventilatorer.

**3.** Brændselscellesystem (10) ifølge krav 1 eller 2, **kendetegnet ved, at** ventilatorerne (20) har forskellig mærke- eller maksimaleffekt.

**4.** Brændselscellesystem (10) ifølge et af kravene 1 til 3, **kendetegnet ved, at** mindst en ventilator (20) eller kompressor er anbragt i tilførselsluftkanalen (16) og mindst en yderligere ventilator (20) eller kompressor er anbragt i afgangsluftkanalen (18).

**5.** Brændselscellesystem (10) ifølge et af kravene 1 til 4, **kendetegnet ved, at** en indgangsåbning af tilførselsluftkanalen (16) og en udgangsåbning af afgangsluftkanalen (18) er anbragt på samme side af brændselscellesystemets (10) hus (22), således at en U-formet luftføring opstår.

**6.** Brændselscellesystem (10) ifølge krav 5, **kendetegnet ved, at** brændselscellesystemet (10) har en bypass-luftkanal (32), der fører fra afgangsluftkanalen (18) til tilførselsluftkanalen (16).

**7.** Brændselscellesystem (10) ifølge krav 6, **kendetegnet ved, at** der i bypass-luftkanalen (32) er anbragt en indretning til styret ændring af bypass-luftkanalens (32) hydrauliske diameter til valgfri åbning eller lukning af bypass-luftkanalen (32).

**8.** Brændselscellesystem (10) ifølge krav 7, **kendetegnet ved, at** der i tilførselsluftkanalen (16) og/eller afgangsluftkanalen (18) er anbragt en indretning til styret ændring af tilførselsluft- eller afgangsluftkanalens (18) hydrauliske diameter til valgfri åbning eller lukning af tilførselsluftkanalen (16) og/eller af afgangsluftkanalen (18).

**9.** Brændselscellesystem (10) især ifølge et af kravene 1 til 8 med et hus (22) med et kammer (12) til optagelse af en brændselscellestak (14) samt med en tilførselsluftkanal (16) til tilførsel af omgivelsesluft til kammeret (12) og en afgangsluftkanal (18) til bortledning af luft fra kammeret (12) til omgivelserne, samt med mindst en ventilator (20) eller kompressor, der er anbragt i tilførselsluftkanalen (16) eller afgangsluftkanalen (18), **kendetegnet ved, at** der til ventilatoren (20) eller kompressoren er tilordnet en luftklap, der er fjederbelastet i driftstilstand og virker som trykreduktionselement, til optimering af kompressorens eller ventilatorens (20) arbejdspunkt i delbelastningsområdet, hvor luftklappen ved fuld belastning kan åbnes, således at den så ikke virker som trykreduktionselement.

**10.** Brændselscellesystem (10) ifølge et af kravene 1 til 9, **kendetegnet ved, at** kammeret (12) er udformet til optagelse af en brændselscellestak (14) på en sådan måde, at brændselscellestakken (14) er anbragt skråt i forhold til kammeret (12).

**11.** Brændselscellesystem (10) ifølge krav 10, **kendetegnet ved, at** brændselscellestakken (14) er anbragt skråt i forhold til husets (22) ydervægge.

**12.** Brændselscellesystem (10) ifølge et af kravene 1 til 11, **kendetegnet ved, at** huset (22) er udformet varmeisolerende.

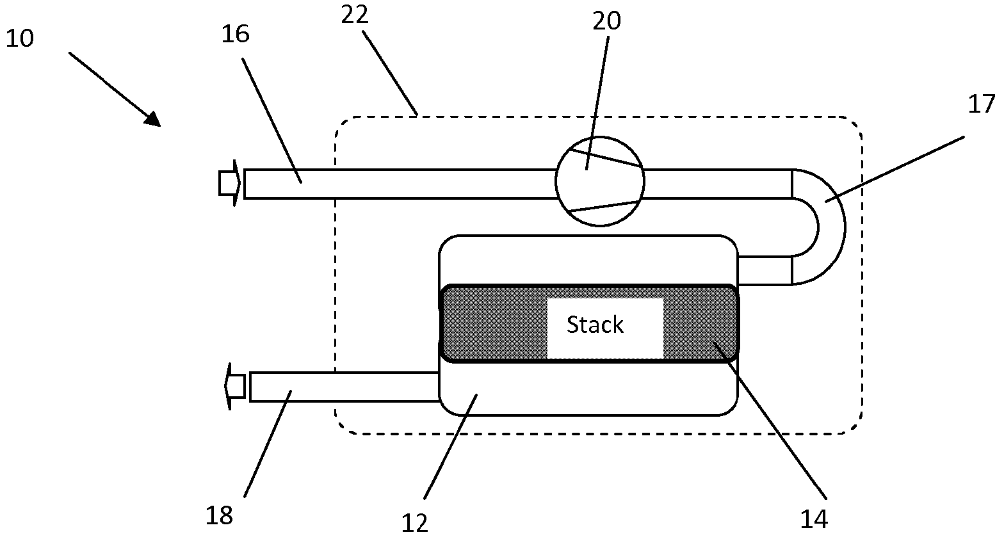


Fig. 1

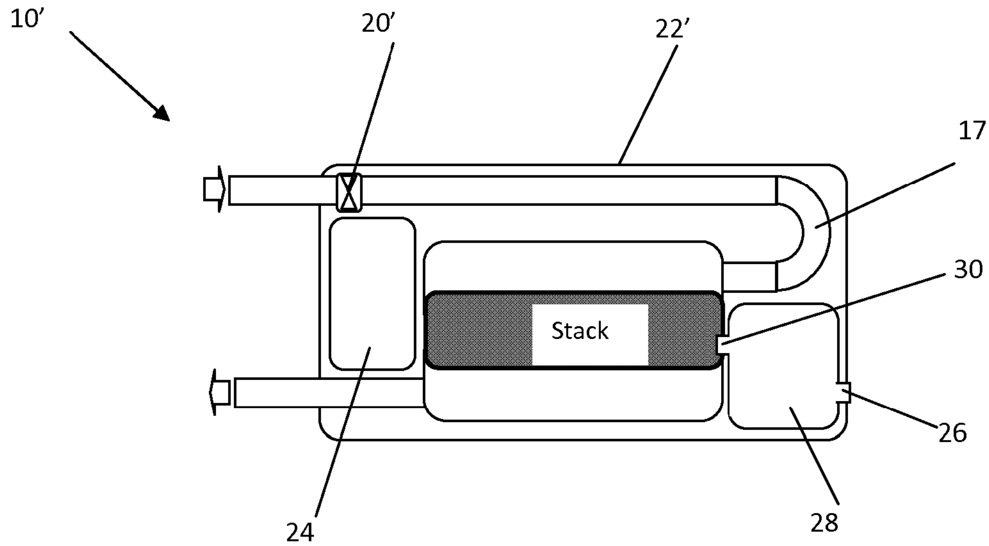


Fig. 2

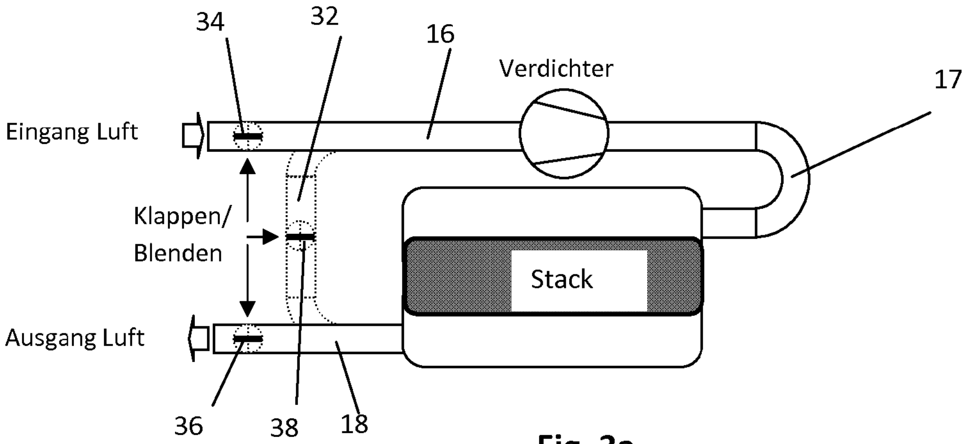


Fig. 3a

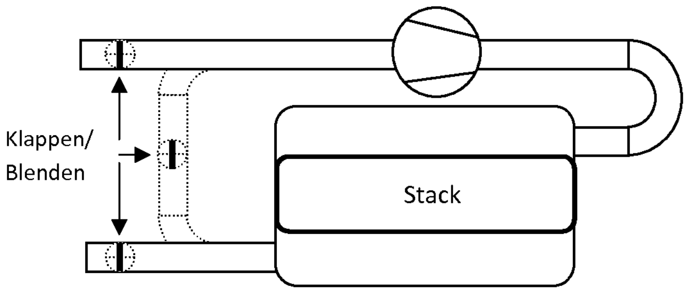


Fig. 3b

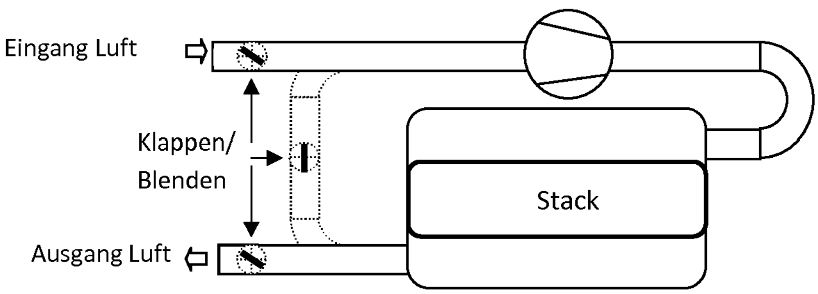


Fig. 3c

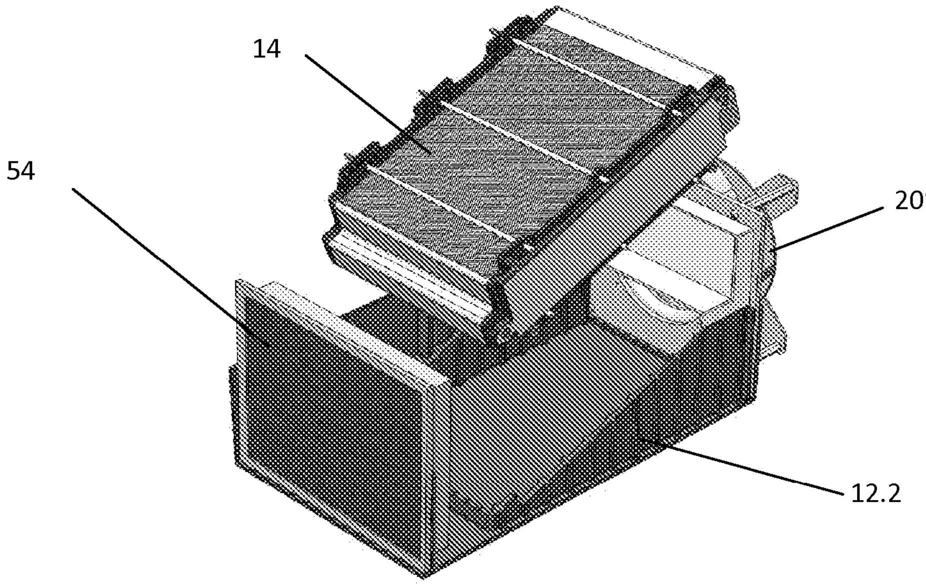


**Fig. 4a**

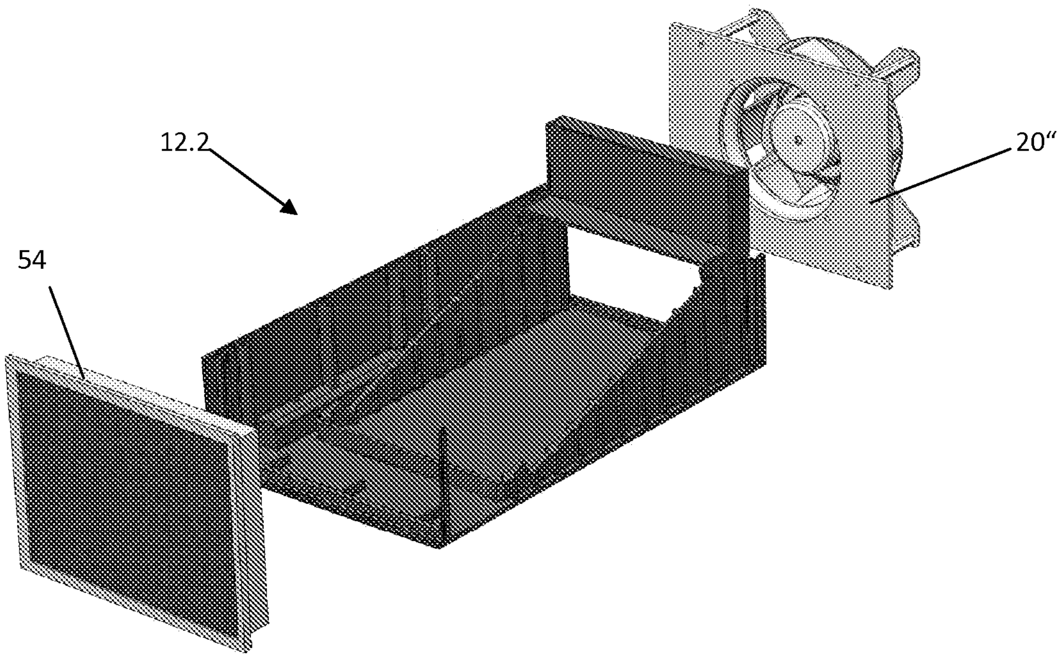


**Fig. 4b**

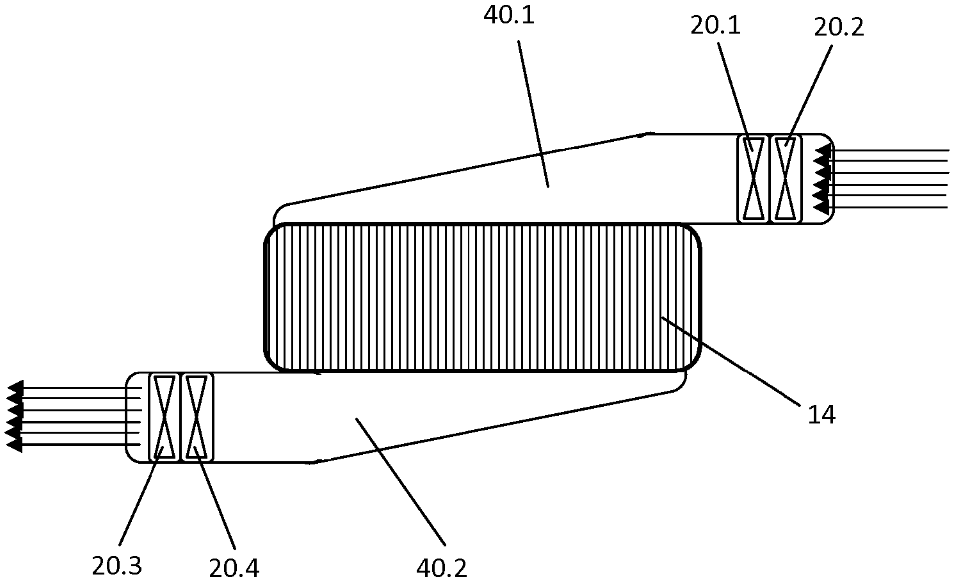


**Fig. 5**

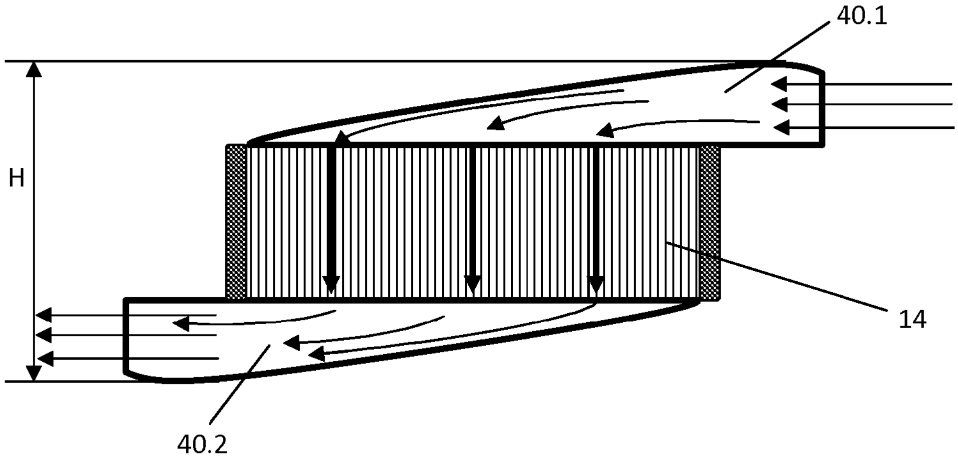


Fig. 6

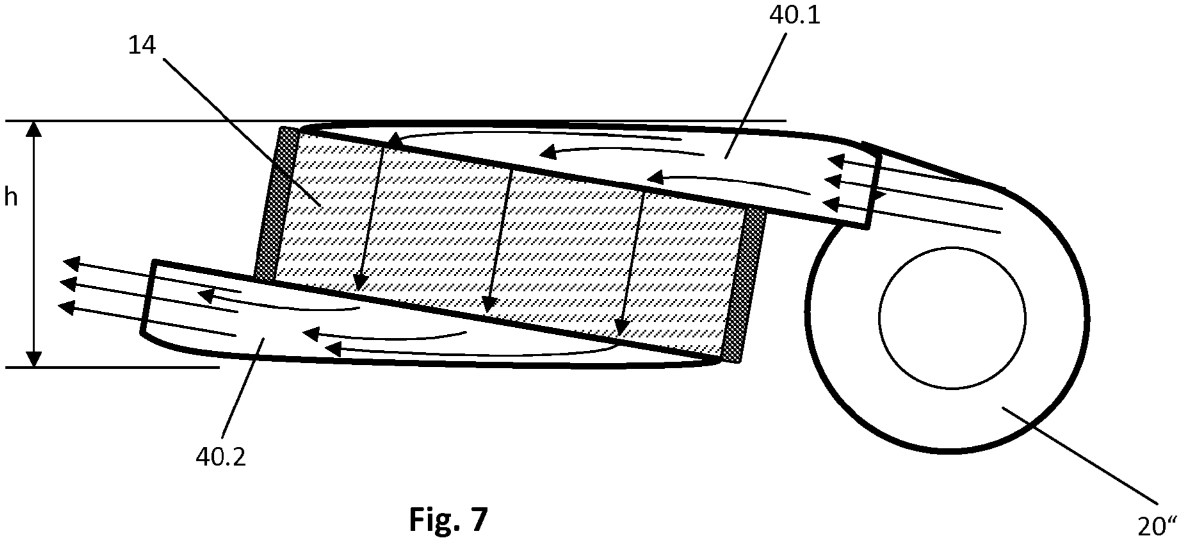


Fig. 7

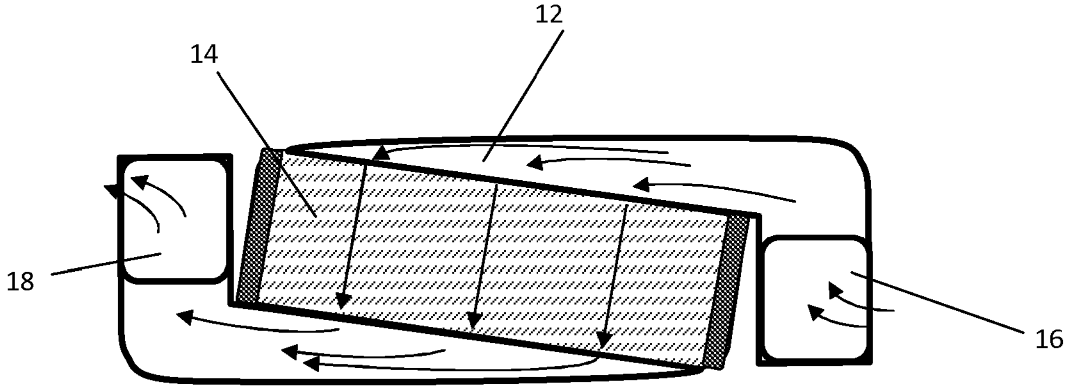


Fig. 8

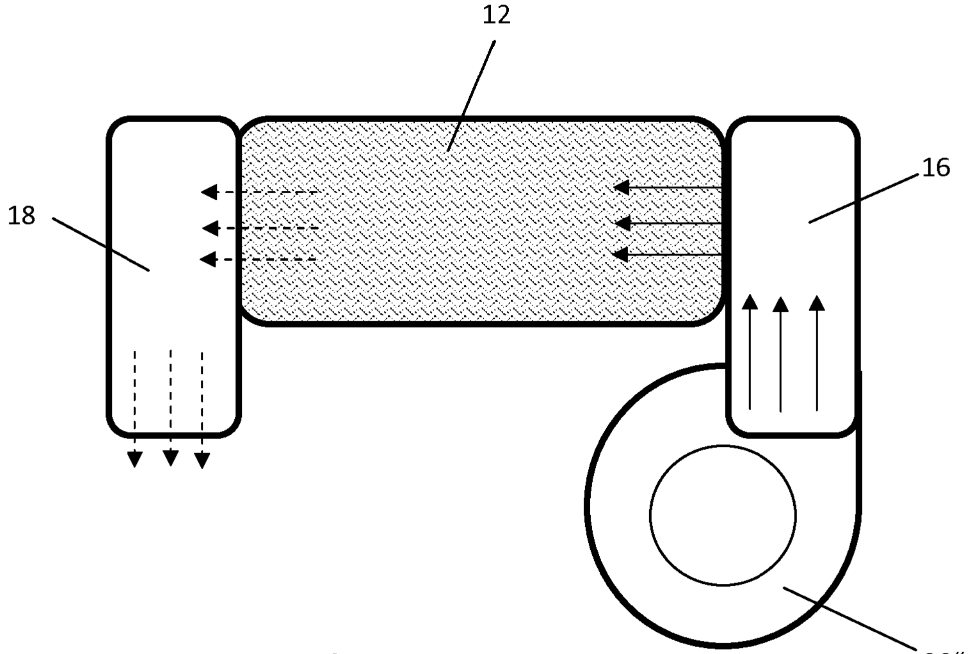
12
16
18
20“

Fig. 9

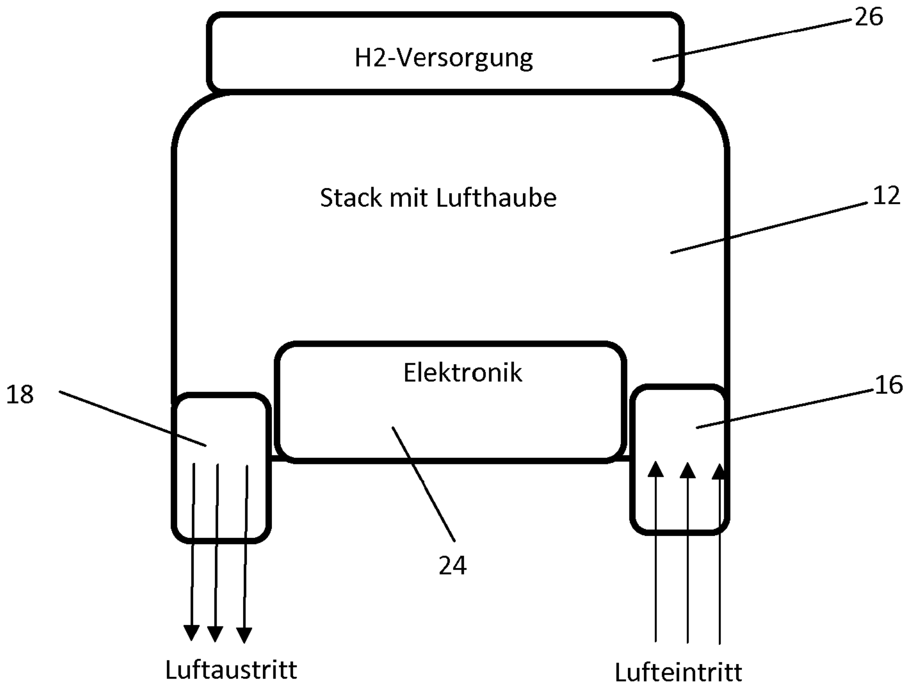
26
H2-Versorgung
Stack mit Lufthaube
12
Elektronik
18
16
24
Luftaustritt
Lufteintritt

Fig. 10