



(51) International Patent Classification:  
*F01N 3/20* (2006.01)

(21) International Application Number:  
PCT/EP2018/073722

(22) International Filing Date:  
04 September 2018 (04.09.2018)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
17306140.9 04 September 2017 (04.09.2017) EP

(71) Applicant: **PLASTIC OMNIUM ADVANCED INNOVATION AND RESEARCH** [BE/BE]; Rue de Ransbeek, 310, 1120 BRUXELLES (BE).

(72) Inventors: **MONGE-BONINI, Beatriz**; Mont du Cinquantenaire, 1, bte7, 1040 Bruxelles (BE). **DOUGNIER, François**; Bieststraat, 15, 3191 HEVER (BE). **DE MAN, Pierre**; clos des Frères Lumière, n°2, bte 8, 1090 BRUXELLES (BE). **SCHWEICHER, Julien**; rue de Tervaele, 16, 1040 ETTERBEEK (BE). **VAN SCHAFTINGEN, Jules-Joseph**; avenue S. de Walhain, 2, 1300 WAVRE (BE).

(74) Agent: **LLR**; 11, boulevard de Sébastopol, 75001 Paris (FR).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,

HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

**Published:**

- with international search report (Art. 21(3))
- in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE

(54) Title: METHOD AND DEVICE FOR INCREASING THE UREA CONCENTRATION OF A UREA SOLUTION ON BOARD OF A VEHICLE

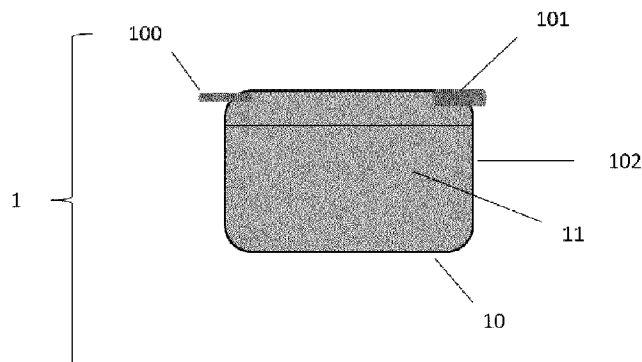


Fig. 1

(57) Abstract: The invention relates to a method and a device for increasing the urea concentration of a urea solution in a container of a vehicle. Said method comprising the steps of: a) flowing a first gas above a first urea solution and/or blowing a second gas in the first urea solution, b) Obtaining a second urea solution the urea concentration of the second urea solution being higher than the urea concentration of the first urea solution.



## **Method and Device for increasing the urea concentration of a urea solution on board of a vehicle**

### **Technical field of the invention**

The invention relates to a device and method for increasing the urea concentration of a urea solution on-board of a vehicle. The invention is also related to a vehicle provided with a device for increasing the urea concentration of a urea solution on-board of a vehicle.

### **Background of the invention**

5 Ammonia is used as reducing agent in a SCR (Selective Catalytic Reduction) system or as fuel in fuel cells, said ammonia being used in a fuel cell such as a Solid Oxide Fuel Cell (SOFC) or as a fuel precursor (i. e.  $H_2$  for all fuel cell types). This ammonia may be obtained by using different techniques. One known technique is based on the use of an ammonia precursor which is a urea  
10 solution, preferably an aqueous urea solution. Typically, the aqueous urea solution available contains about 32. 5% by weight high-purity urea and 67. 5% deionized water. The high purity urea is defined according to the standard ISO 22241. An example of such ammonia aqueous solution is commercialized under the trademark Adblue®. Generally, such urea solution is stored in a tank mounted on  
15 the vehicle.

A SCR (Selective Catalytic Reduction) system converts nitrogen oxides of an exhaust gas coming from a vehicle engine into diatomic nitrogen and water. The SCR system enables the reduction of nitrogen oxides by injection of ammonia into the exhaust line. This ammonia may be obtained by injecting a urea  
20 solution into the exhaust line, and the gaseous ammonia is derived from the pyrolytic (thermal) decomposition of the injected urea solution.

Urea, containing 86 grams of H<sub>2</sub> per cubic decimeter, is an excellent way of storing and transporting hydrogen that can be used to as fuel. This hydrogen may for example be obtained by thermal decomposition in high temperature fuel cells or by using a thermal reformer producing an hydrogen rich gas stream that can then feed a fuel cell.

A problem with the known technique is that the urea concentration in urea solution is relatively low regarding the new regulation requirement in the case of a SCR system or to the high volume of ammonia needed to feed a fuel cell for electrical power generation.

Methods and devices that increase urea concentration in urea solutions are disclosed in documents CN 205307829 U, US 2015218089 A1, DE 102006059760, JPS 57171956, GB 177056. Nevertheless all the disclosed methods and devices are not provided for increasing the urea concentration of a urea solution on board of a vehicle due to for example the use of high temperatures for water evaporation, the energy demanding, the filtration systems used to perform the water separation, the use of membrane that has to be periodically replaced and/or the use of vacuum conditions, typically 0,5 to 800 mb under ambient pressure, The document CN 205307829 U discloses a method where urea is evaporated and condensate in an energy demanding system comprising a plurality of heaters, steam condensate separators and a steam condensate tank, which requires high energy consumption. Another drawback is the complexity of the system that requires a plurality of steps in order to remove the water.

The document US 2015218089 A1 discloses a method where an aqueous solution is concentrated by means of contact with a water-selective membrane. The water-selective membrane is permeable to water and substantially impermeable to other constituents in the aqueous solution; an aqueous solution of urea feed one side of the membrane, and a flow composed mainly of water is obtained at the discharge side. Pressure on the feed side may be needed to

enhance the process. An inconvenience of this method is that the water accumulated at the discharge side of the membrane has to be eliminated, bringing additional complexity to the system. Another inconvenience is that the membrane has to be periodically replaced.

5 DE 102006059760 describes a process and a plant for the preparation of an aqueous solution of urea suitable for use in a SCR process, wherein the urea solution is subject to at least one step of evaporation, in order to separate vapor stream containing water from ammonia, in order to obtain a concentrated and substantially ammonia-free solution. The evaporation step  
10 comprises a heating step and a further step including a subsequent separation under vacuum, where the vapor stream containing water and ammonia is separated from the concentrated solution. Equipment running under vacuum poses a problem of sealing to avoid infiltration of air from the outside. Another problem is the poor energy efficiency since a vacuum evaporator requires heat  
15 input. A further problem with equipment used under vacuum is that it requires a vacuum safe seal in order to prevent air leakage.

The document JPS 57171956 describes a method for concentrating an aqueous solution of urea by dispersing the solution with a sprayer such as pressurized nozzle atomizer in the form of fine droplets, which contact hot air of  
20 at least 132 degrees centigrade, in a concentration zone in order to evaporate the water contained therein. The disadvantage of this method is the complex design of the evaporator design, which requires a sophisticated control device.

The document GB177056 discloses a method for obtaining urea in granular form by spraying urea solution into contact with a warm gaseous drying  
25 medium. The urea solution, preferably previously concentrated under vacuum, is distributed horizontally in the form of mist into a current of gaseous drying medium, which is so directed as not to disturb the horizontal flow of the mist. Almost completely dehydrated urea is obtained. The drawback is again the complexity of this system.

There is thus a need of a method that increases urea concentrations solutions on board of a vehicle and a device that increases urea concentration solutions on board of a vehicle and of a vehicle system comprising said device in order to increase urea concentration solutions on board of a vehicle.

### Summary of the invention

5                   It is an object of the invention to provide a method that increases the urea concentration of a urea solution, preferably an aqueous urea solution, on board of a vehicle.

                  It is another object of the invention to provide a device that increases urea concentration in solutions on board of a vehicle in order to increase  
10               the urea concentration of a urea solution, preferably an aqueous urea solution.

                  It is another object of the invention to provide a vehicle system that increases the urea concentration of a urea solution, preferably an aqueous urea solution.

                  The above objectives are accomplished by a method, device and  
15               system according to the invention.

                  According to a first aspect of the invention there is provided a method for increasing the urea concentration of a urea solution in a container on board of a vehicle, preferably a moving vehicle, said method comprising the steps of:

20               a) flowing a first gas above a first urea solution and/or blowing a second gas in the first urea solution in the container on board of the vehicle,

- b) Obtaining a second urea solution, the urea concentration of the second urea solution being higher than the urea concentration of the first urea solution.

The inventors have found that the step of a) flowing a first gas above the first urea solution and/or blowing a second gas in the first urea solution in a container on board of a vehicle increases the urea concentration of said first urea solution. Said step a) provides the evaporation of the solvent of the first urea solution increasing the concentration of the urea in said solution and obtaining a second urea solution, the urea concentration of the second urea solution being higher than the urea concentration of the first urea solution. Furthermore, the method according to the invention provides a progressive removal of the solvent, preferably water, from the first urea solution. More particularly, the method according to the invention requires reduced energy and avoids or reduces the employment of consumables such as electricity; in particular, the method can use low quality energy (i. e. energy at low temperature, typically less than 120°C). The method also allows earlier refilling of the tank and increases thus the driving range that can be reached by the vehicle in combination with practical refilling scenarios. In addition, one main advantage is that the energy required to handle the solution with reduced water content is lower than with the initial water content. This is especially important as the handling of additional water requires more high quality energy (i. e. energy at temperature above 120°C) in the downstream process, where urea is converted to ammonia. Preferably, the first urea solution is an Adblue® solution (urea 32.5 weight %).

According to a preferred embodiment of the method for increasing the urea concentration of a urea solution in a container on board of a vehicle comprising a device according to the invention, when the first gas and/or the second gas is (are) selected from the group consisting of air, exhaust gas and their mixtures. By the terms “exhaust gas”, we intend to mean the exhaust gas from both cathode and/or anode side of a fuel cell, the exhaust gas from a burner (conversion unit/ cracker) or afterburner, the exhaust gas from the endline of a

DeNOx system (i. e. the exhaust gas from the end line of the gas treatment system in a diesel engine) or any mixture of this exhaust gas with air coming from the environment. These gases which might be initially at high temperatures may be used to heat up other devices (using for instance heat exchangers), in order to  
5 recover their energy as much as possible, before being sent to the container containing the urea solution.

According to a preferred embodiment of the method according to the invention for increasing the urea concentration a urea solution in a container, the first gas and the second gas are identical.

10 One of the advantages related to the use of identical gases relies to the fact that a less complex device structure is required for the blowing and the flowing of the gas in and above the urea solution. According to a preferred embodiment, the method according to the invention for increasing the urea concentration of a first urea solution in a container, the first gas and the second  
15 gas of step a) have a temperature comprised in the range of 0°C to 600°C, preferably in the range of 10°C to 200°C, more preferably in the range of 15 °C to 100°C.

The inventors have surprisingly found that the use of a first gas and a second gas having a temperature comprised in said ranges enable an efficient  
20 removal of the water.

According to a preferred embodiment, the method according to the invention for increasing the urea concentration of a first urea solution in a container comprises a step c) of adding a third urea solution to the second urea solution. Preferably, the urea concentration of the third urea solution is equal or  
25 lower than the urea concentration of the second urea solution.

According to a second aspect of the invention there is provided a device for increasing the urea concentration of a first urea solution in a vehicle, said device comprising a urea solution container, wherein said urea solution

container comprises a gas inlet and a gas outlet, said gas outlet being located above the level of the first urea solution in said urea solution container.

According to a preferred embodiment, the device according to the invention for increasing the urea concentration of a first urea solution comprises a urea solution container comprising a means for increasing solvent evaporation. The means for increasing the solvent evaporation increases the speed of water evaporation and increases thus the concentration in the remaining liquid.

According to a preferred embodiment, the device according to the invention for increasing the urea concentration of a first urea solution is provided with means for increasing solvent evaporation comprising capillarity enhancer means. Capillarity enhancer means increases the water exchange area and increases thus the water evaporation speed.

According to a preferred embodiment of the device according to the invention for increasing the urea concentration of a first urea solution the capillarity enhancer means are fixed on said urea solution container and/or floating on the surface of the first urea solution. Capillarity enhancer means increases the surface evaporation and increases thus the water evaporation speed.

According to a preferred embodiment of the device according to the invention for increasing the urea concentration of a first urea solution the gas inlet is located above and/or under the level of the first urea solution in said container. The choice of location of gas inlet depends on the design of the system comprising the device according to the invention. A gas inlet may be provided with a non-return valve (e.g. a check valve) in order to prevent liquid from flowing back into the venting circuit.

According to a preferred embodiment of the device according to the invention for increasing the urea concentration of a first urea solution said urea solution container comprises a plurality of gas inlets. The use of a plurality of gas inlets ensures a better flow distribution that increases the evaporation rate.

According to a preferred embodiment of the device according to the invention for increasing the urea concentration of a first urea solution said urea solution container comprises a plurality of gas inlets and/ a plurality of gas outlets. The use of a plurality of gas inlets and/or a plurality of gas outlets ensures  
5 a better flow distribution that increases the evaporation rate.

According to a preferred embodiment of the device according to the invention for increasing the urea concentration of a first urea solution said urea solution container comprises a heater. The heater heats the solution and increases the evaporation rate. A further advantage of the heater is that it can be  
10 used for thawing the frozen solution.

According to a preferred embodiment of the device according to the invention for increasing the urea concentration of a first urea solution said urea solution container is a first urea solution reservoir or a desiccation chamber.

According to a further embodiment, a vehicle system comprising a  
15 device according to the invention for increasing the urea concentration of a first urea solution is provided in a vehicle. Such a vehicle system provides more efficient vapor evaporation in order to concentrate the urea solution than prior art systems.

An advantage of the device and the method according to the  
20 invention is that the disclosed evaporation enable an earlier refilling and provides therefore an increased driving range.

A further advantage of the device and the method according to the invention is that the higher urea concentration is obtained using energy at lower temperature than according to prior art. The herein disclosed method, device and  
25 system use low temperature energy which at no extra cost is available on the car. Thus the invention is more environmental friendly.

Particular and preferred aspects of the invention are set out in the accompanying independent and dependent claims. Features from the dependent

claims may be combined with features of the independent claims and with features of other dependent claims as appropriate and not merely as explicitly set out in the claims.

Although there has been constant improvement, change and evolution of devices in this field, the present concepts are believed to represent substantial new and novel improvements, including departures from prior practices, resulting in the provision of more efficient, stable and reliable devices of this nature.

The above and other characteristics, features and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention. This description is given for the sake of example only, without limiting the scope of the invention. The reference figures quoted below refer to the attached drawings.

## 5. Brief description of the figures

The accompanying drawings are used to illustrate presently preferred non-limiting exemplary embodiments of devices of the present invention. The above and other advantages of the features and objects of the invention will become more apparent and the invention will be better understood from the following detailed description when read in conjunction with the accompanying drawings, in which:

- Figure 1 is a side view illustrating schematically an exemplary embodiment of the device for increasing the urea concentration of a first urea solution;
- Figure 2 is a side view illustrating schematically a first variant of the device according to the invention for increasing the urea concentration of a first urea solution ;

- Figure 3 shows schematically a second variant of the device according to the invention for increasing the urea concentration of a first urea solution ;
- 5 • Figure 4A is a side view and Figure 4B is a top view that represent schematically a third variant of the device according to the invention for increasing the urea concentration of a first urea solution ;
- Figure 5A is a side view and 5B is a top view that illustrate schematically a fourth variant of the device according to the invention for increasing the urea concentration of a first urea solution ;
- 10 • Figure 6 is a side view that illustrates schematically a fifth variant of the device according to the invention for increasing the urea concentration of a first urea solution ;
- Fig. 7 is a side view that represents schematically a sixth variant of the of the device according to the invention for increasing the urea concentration of a first urea solution ;
- 15 • Figure 8 is a side view that illustrates schematically a seventh variant of the device according to the invention for increasing the urea concentration of a first urea solution ;
- Figure 9 is a side view that illustrates schematically an eight variant of the device according to the invention for increasing the urea concentration of a first urea solution.
- 20 • Fig. 10 is a side view that is illustrates schematically a ninth variant of the device according to the invention for increasing the urea concentration of a first urea solution

- Fig. 11 is a side view of an alternative to the device shown in fig. 10 according to the invention for increasing the urea concentration of a first urea solution
- Fig. 12 is a side view of an alternative to the device shown in fig. 10 according to the invention for increasing the urea concentration of a first urea solution
- Fig. 13 is a side view of an alternative to the device shown in fig. 10 according to the invention for increasing the urea concentration of a first urea solution

## 10 Description of illustrative embodiments

The present invention will be described with respect to particular embodiments and with reference to certain drawings but the invention is not limited thereto but only by the claims. The drawings described are only schematic and are non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn on scale for illustrative purposes. The dimensions and the relative dimensions do not correspond to actual reductions to practice of the invention.

Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequence, either temporally, spatially, in ranking or in any other manner. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

Moreover, the terms top, bottom, over, under and the like in the description and the claims are used for descriptive purposes and not necessarily for describing relative positions. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the

invention described herein are capable of operation in other orientations than described or illustrated herein.

It is to be noticed that the term “comprising”, used in the claims, should not be interpreted as being restricted to the means listed thereafter; it does not  
5 exclude other elements or steps. It is thus to be interpreted as specifying the presence of the stated features, integers, steps or components as referred to, but does not preclude the presence or addition of one or more other features, integers, steps or components, or groups thereof. Thus, the scope of the expression “a device comprising means A and B” should not be limited to devices consisting  
10 only of components A and B. It means that with respect to the present invention, the only relevant components of the device are A and B.

Similarly, it is to be noticed that the term “coupled”, also used in the claims, should not be interpreted as being restricted to direct connections only. The terms “coupled” and “connected”, along with their derivatives, may be used.  
15 It should be understood that these terms are not intended as synonyms for each other. Thus, the scope of the expression “a device A coupled to a device B” should not be limited to devices or systems wherein an output of device A is directly connected to an input of device B. It means that there exists a path between an output of A and an input of B which may be a path including other  
20 devices or means. “Coupled” may mean that two or more elements are either in direct physical or electrical contact, or that two or more elements are not in direct contact with each other but yet still co-operate or interact with each other.

Reference throughout this specification to “one embodiment” or “an embodiment” means that a particular feature, structure or characteristic described  
25 in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment, but may. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner, as  
30 would be apparent to one of ordinary skill in the art from this disclosure, in one or more embodiments.

Similarly it should be appreciated that in the description of exemplary embodiments of the invention, various features of the invention are sometimes grouped together in a single embodiment, figure, or description thereof for the purpose of streamlining the disclosure and aiding in the understanding of one or more of the various inventive aspects. This method of disclosure, however, is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment. Thus, the claims following the detailed description are hereby expressly incorporated into this detailed description, with each claim standing on its own as a separate embodiment of this invention.

Furthermore, while some embodiments described herein include some but not other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the invention, and form different embodiments, as would be understood by those in the art. For example, in the following claims, any of the claimed embodiments can be used in any combination.

Furthermore, some of the embodiments are described herein as a method or combination of elements of a method that can be implemented by a processor of a computer system or by other means of carrying out the function. Thus, a processor with the necessary instructions for carrying out such a method or element of a method forms a means for carrying out the method or element of a method. Furthermore, an element described herein of an apparatus embodiment is an example of a means for carrying out the function performed by the element for the purpose of carrying out the invention.

In the description provided herein, numerous specific details are set forth. However, it is understood that embodiments of the invention may be practiced without these specific details. In other instances, well-known methods, structures and techniques have not been shown in detail in order not to obscure an understanding of this description.

The following terms are provided solely to aid in the understanding of the invention.

By the terms “first urea solution reservoir”, we intend to mean that the urea solution container is the reservoir used to store the urea solution and that the steps of a) flowing a first gas above a first urea solution and/or blowing a second gas in the first urea solution in the container of the vehicle and b) obtaining a second urea solution the urea concentration of the second urea solution being higher than the urea concentration of the first urea solution are performed in said reservoir.

By the terms “desiccation chamber”, we intend to mean that the urea solution container is a supplemental container, said urea solution container being different from the reservoir used to store the urea solution, said urea solution container being used to perform the steps of a) flowing a first gas above a first urea solution and/or blowing a second gas in the first urea solution in the urea solution container of the vehicle and b) obtaining a second urea solution the urea concentration of the second urea solution being higher than the urea concentration of the first urea solution.

By the term “conversion unit” we intend to mean a chamber where urea is converted into ammonia.

By the term “jacketed device”, we intend to mean a container that is designed for controlling the temperature of its contents by using a cooling or heating jacket around the vessel through which a cooling or heating fluid is circulating.

Figure 1 illustrates an exemplary embodiment of device according to the invention for increasing the urea concentration of a first urea solution. The device 1 comprises a urea solution container 10 comprising a first urea solution 11, said urea solution container 10 comprising a gas inlet 100 and a gas outlet 101, said urea solution container being a first urea solution reservoir 102. In said

urea solution container 10, the increasing of the urea concentration in the urea solution is performed by a) flowing a first gas above a first urea solution. The first gas flow may be provided for example by the car exhaust system or by the gas flow coming out of a fuel cell system. In the example of figure 1 the first gas enters the urea water solution container through a gas inlet and exits via a gas outlet carrying away the evaporated water. Hot gas is used both to supply the heat for evaporation and to carry away the evaporated moisture from the urea water solution.

Figure 2 illustrates schematically a first variant of the device according to the invention for increasing the urea concentration of a first urea solution in a vehicle according to the invention. The device 1 comprises a urea solution container 10 comprising a first urea solution 11, said urea solution container 10 comprising a gas inlet 100 and a gas outlet 101, said urea solution container 10 being a first urea solution reservoir 102. In said urea solution container 10, the concentration of urea in the urea solution is increased by performing the step of a) flowing a first gas above a first urea solution. The urea solution container 10 comprises a means for increasing solvent evaporation 103. Said means for increasing solvent evaporation 103 comprises heat exchange media material 1030 to increase the water surface for evaporation. The heat exchange media material 1030 has capillary effect in the presence of urea water solution. The capillary effect conveys the urea solution into the gas flow offering an increased surface for exchange. Here, the heat exchange media material 1030 is preferably immersed directly in the urea solution and provides thereby solution directly into the gas flow. The first urea solution is preferably an Adblue® solution (urea 32.5 weight %).

Figure 3 illustrates schematically a second variant of the device according to the invention for increasing the urea concentration of a first urea solution. The device 1 comprises a urea solution container 10 comprising a first

urea solution 11, said urea solution container 10 comprising a gas inlet 100 and a gas outlet 101, said urea solution container 10 being a first urea solution reservoir 102. In said urea solution container 10, the concentration of urea in the urea solution is increased by performing the step of a) providing a first gas flow above a first urea solution. The urea solution container 10 comprises a means for increasing solvent evaporation 103. Said means for increasing solvent evaporation 103 comprises an exchange media material 1030 that increases the water surface for evaporation. The exchange media material 1030 has capillary effect in the presence of urea water solution. The exchange media material 1030 is located at the liquid surface in order to increase the water surface area for evaporation. The exchange media material 1030 may be equipped with capillarity enhancer pins or thin tubes 1031. The capillarity enhancer pins 1031 have a design which employs capillary action to draw up the water and propell it to the surface of the exchange media. The structure of the exchange media material 1030 improves liquid spreading and, in addition, increases the area where the evaporation occurs. The exchange media material 1030 can be floating on the surface and/or attached to the wall or to any other internal components in the urea solution container 10. Examples of exchange media materials are nylon, cellulose, and nitrocellulose. The first urea solution is preferably an Adblue® solution (urea 32.5 weight %).

Figure 4 A and 4B shows an improved version of the previous embodiment and represent schematically a third variant of the device according to the invention for increasing the urea concentration of a first urea solution on board. The device 1 comprises a urea solution container 10 comprising a first urea solution 11, said urea solution container 10 comprising a plurality gas inlet 100 and a plurality of gas outlet 101, said urea solution container 10 being a first urea solution reservoir 102. In said urea solution container 10, the concentration of urea in the urea solution is increased by performing the step of a) flowing a first gas above a first urea solution. The urea solution container 10 comprises a means for increasing solvent evaporation 103. Said means for increasing solvent evaporation 103 comprises an exchange media material 1030 that increases the

water surface for evaporation. The use of a plurality of gas inlets 100 and/or a plurality of gas outlets 101 ensures a better flow distribution increasing the evaporation rate.

Fig 5A and 5B illustrate schematically a fourth variant of the device according to the invention for increasing the urea concentration of a first urea solution. The device 1 comprises a urea solution container 10 comprising a first urea solution 11, said urea solution container 10 comprising a plurality gas inlets 100 and a plurality of gas outlets 101, said urea solution container 10 being a first urea solution reservoir 102. In said urea solution container 10, the concentration of urea in the urea solution is increased by performing the step of a) flowing a first gas above a first urea solution. The urea solution container 10 comprises a means for increasing solvent evaporation 103. Said means for increasing solvent evaporation 103 comprises an exchange media material 1030 that increases the water surface for evaporation. The first gas is supplied by an air stream (illustrated by solid arrows) generated by the movement of a car in which the device according to the invention is located. The car is represented on fig. 5B by the two front wheels 30, 31, the two rear wheels 32, 33, the front bumper 34 and the rear bumper 35. Said first gas is used as a carrier of evaporated moisture. For example, assuming a car is moving at 20 m/sec and that air is collected on a surface of 200 mm<sup>2</sup> (equivalent to a tube having an inner diameter of 16 mm), more than 10000 l/h air is collected. . Thus, very high flow rates can be achieved. Table I presents the urea concentrations evolution obtained depending on the air flow rate and evaporation time. The examples show the urea concentration that can be obtained when air flows at a rate of 2000 up to 6000 l/h at a temperature of 40°C. The water saturation vapor pressure is a function of temperature and at 40°C the water saturation vapor pressure is 7385 Pascal. Under the described conditions, four liters of urea water solution at 32,5% (w/w) can progressively be concentrated with increasing air flow rates reaching 38% (w/w) urea concentration after 2 hours of evaporation, 45% (w/w) after 4 hours and 75%

(w/w) (concentration close to the aqueous equimolar urea solution what typically contains 77% urea) after 8 hours of continuous evaporation.

Table I: urea concentrations evolution depending on the air flow rate and evaporation time.

5

| Urea concentration (wt%) |                     |                        |                  |      |      |
|--------------------------|---------------------|------------------------|------------------|------|------|
| Air flow rate<br>(l/h)   | Temperature<br>(°C) | Vapor<br>pressure (Pa) | Evaporation time |      |      |
|                          |                     |                        | 2h               | 4h   | 8h   |
| 2000                     | 40                  | 7385                   | 34,1             | 35,9 | 40,1 |
| 3000                     | 40                  | 7385                   | 35,0             | 37,9 | 45,4 |
| 4000                     | 40                  | 7385                   | 35,9             | 40,1 | 52,3 |
| 5000                     | 40                  | 7385                   | 36,9             | 42,6 | 61,6 |
| 6000                     | 40                  | 7385                   | 37,9             | 45,4 | 75,1 |

Figure 6 illustrates schematically a fifth variant of the device according to the invention for increasing the urea concentration of a first urea solution. The device 1 comprises a urea solution container 10 comprising a first urea solution 11, said urea solution container 10, said urea solution container being a first urea solution reservoir 102. The device 1 comprises also a urea solution container 10 comprising a first urea solution 11, said container 10 comprising at least one gas inlet 100 and at least one gas outlet 101, said urea solution container 10 being a desiccation chamber 104. The desiccation chamber 104 is located outside the first urea solution reservoir 102. A pump 14 connects the first urea solution reservoir 102 to the desiccation chamber 104. The device comprises also a cathode or anode fuel cell system 12 coupled to the inlet 100 of the desiccation chamber 104. It should be noted that the fuel cell system 12 is not directly connected to the desiccation chamber 104. The desiccation chamber is connected to a conversion unit (not shown) that is connected to the fuel cell system 12.

The first urea solution 11 contained in the first urea reservoir 102 is injected into the desiccation chamber 104 via the pump 14. In the desiccation chamber 104, the concentration of urea in the urea solution is increased by performing the steps of a) flowing a first gas flow above a first urea solution illustrated by solid arrows, the urea solution being provided by a pump 14, pumping the first urea solution 11 from the first urea solution reservoir 102 to the desiccation chamber 104. The first urea solution 11 is preferably an Adblue® solution (urea 32.5 weight %). The gas flow is provided by the cathode or anode of the fuel cell system 12. For example, the gas flow provided by the cathode side of a 20 kilowatt fuel cell is around 2000 liters/minute or 120000 l/h. In the table II, different urea concentrations are obtained depending on the temperature and evaporation time at a constant gas flow rate of 2000 l/h. The saturation pressure of water increases with temperature. In this example, the volume of urea water solution in the desiccation chamber is four liters. When the temperature is increased, the urea concentration increases. For example, urea water solution at 32,5% (w/w) can be concentrated to 34% (w/w) after 2 hours evaporation at 40°C, 37% (w/w) at 60°C and 44,5% (w/w) after 2 hours at 80°C. The urea concentration increases even faster when the exhaust gases from a SOFC (Solid Oxide Fuel Cell) are being used. The exhaust gases have a temperature superior to 500°C. The heat passes typically through a heat exchanger where air is heated. The heated air flow is then used to heat the tank, thanks to the high temperature (> 500°C). The pump provides more efficient vapor evaporation. The fact that the desiccation chamber 104 is located outside the first urea solution reservoir 102 facilitates maintenance.

In figure 7 illustrates an alternative embodiment of the device shown in figure 6. According to this embodiment, the desiccation chamber 104 is located inside the first urea reservoir 102, being preferably an AdBlue® reservoir 102.

Tableau II: Urea concentrations evolution depending on the temperature and time for evaporation at a constant gas flow rate of 2000 l/h

| Urea concentration (wt%) |                     |                        |                  |       |       |
|--------------------------|---------------------|------------------------|------------------|-------|-------|
| Air flow rate<br>(l/h)   | Temperature<br>(°C) | Vapor<br>pressure (Pa) | Evaporation time |       |       |
|                          |                     |                        | 2h               | 4h    | 8h    |
| 2000                     | 20                  | 2339                   | 33,0             | 33,6  | 34,7  |
| 2000                     | 40                  | 7385                   | 34,1             | 35,9  | 40,1  |
| 2000                     | 60                  | 19948                  | 36,9             | 42,8  | 62,5  |
| 2000                     | 80                  | 47415                  | 44,5             | 100,0 | 100,0 |

Figure 8 illustrates schematically a seventh variant of the device according to the invention for increasing the urea concentration of a first urea solution. The device 1 comprises a urea solution container 10 comprising a first urea solution 11, said urea solution container 10 comprising a gas inlet 100 and a gas outlet 101, said urea solution container 10 being a first urea solution reservoir 102. In said urea solution container 10, the increasing of the urea concentration in the urea solution is performed by a) blowing a second gas flow in the first urea solution. The second gas flow may be provided for example by the car exhaust system or by the gas flow coming out of a fuel cell system. The second gas flows inside the urea solution by means of a bubbling system, preferably a micro-bubbling system 1001. The gas bubbles, preferably the gas micro-bubbles, travel from the bottom of the urea solution container to the top supplying the heat for evaporation and removing the evaporated moisture from the urea solution. Such a bubbling system, preferably a micro-bubbling system 1001, enhances the evaporation. The solid arrows illustrate the gas flow. It should be noted that gas used for the desiccation can be the exhaust gas, air from the environment, or air from the environment heated by any means, in particular having past through an heat exchanger where it is heated by exhaust gas, which may already has been used to heat the conversion unit.

Figure 9 illustrates schematically a seventh variant of the device according to the invention for increasing the urea concentration of a first urea solution. The device 1 comprises a urea solution container 10 comprising a first urea solution 11, said urea solution container 10 comprising a gas inlet 100 and a

gas outlet 101, said container 10 being a first urea solution reservoir 102. In said container 10, the increasing of the urea concentration in the urea solution is performed by a) providing a first gas flow above a first urea solution (illustrated with solid arrows). The first gas flow may be provided for example from the car exhaust system or by the gas flow coming out of a fuel cell system. The device 1 comprises a heater 15 which heats up the first urea solution 11 generating flow of liquid (heat convection effect illustrated by the curved arrow) and the gas flow enters the urea solution container through a gas inlet 100 and exits via a gas outlet 101 carrying away the evaporated water. The advantage of this embodiment is that warm urea solution will favor water evaporation while decreasing the hot air heat dissipation when in contact with the urea water solution. The heater 15 could be a heat exchanger. In an SCR-system, the heater 15 could also be used to thaw the urea solution in cold conditions as done in the state-of-the-art of SCR systems. In an SCR-system, the heater can be fed by the engine cooling circuit or be powered electrically.

In the case of fuel cell applications, the heater uses the excess of electrical energy when available. The heat can also be provided by gas flow provided from the fuel cell (cathode or anode stream) or the burners, possibly after passing through heat exchangers allowing the recovery of high temperature energy.

Figure 10 illustrates a device according to the invention for increasing the urea concentration of a first urea solution. The device 1 comprises a urea solution container 10, said urea solution container 10 comprising a gas inlet 100 and a gas outlet 101, said urea solution container being a first urea solution reservoir 102.. The device 1 comprises a fuel cell 12 having a cathode side and an anode side. The fuel cell is connected to a heat exchanger 16. The heat exchanger is connected to conversion unit 17 comprising a jacketed device 170. The conversion unit is connected to the gas inlet 100. The exhaust gas coming from the fuel cell 12, for example from the cathode side said fuel cell, travels through the heat exchanger 16 and heats up the conversion unit 17. The conversion unit 17

comprises a jacketed device 170 where the fuel precursor is converted into fuel ready to feed the fuel cell 12. The fuel is then returned through the heat exchanger 16 where it is heated and then provided to the fuel cell 12 that operates at temperature of about 700°C. The exhaust gas, after a passage through the conversion unit 17, has enough residual heat, and is provided to the urea solution container 10 through the gas inlet 100 and exits via the gas outlet 101 removing the evaporated water. The exhaust gas flow is illustrated by the solid arrows, the dashed arrows illustrating the effluents flow.

Figure 11 illustrates schematically an alternative to the previous embodiment of a device according to the invention for increasing the urea concentration of a first urea solution. The device 1 shown on fig. 11 differs from the device in fig. 10 in that a tubular heating element 18 is located inside the urea solution reservoir 102. The exhaust gas coming from the fuel cell 12, for example from the cathode side of a SOFC, travels through the heat exchanger 16 and then heat up the conversion unit 17, said exhaust gas having a temperature between 80°C and 900 °. The conversion unit 17 is a jacketed device 170 where the fuel precursor is converted into fuel ready to feed the fuel cell 12. The fuel is provided sent through the heat exchanger 16, where it is heated, and is then provided to the fuel cell 12 that operates at a temperature of about 700°C. The exhaust gas carrying the residual heat is used to heat up a tubular heating element 18 inside the urea solution reservoir 102. The tubular heater 18 thaws or warms up the urea solution generating hot liquid. Air flows from the environment is provided to the urea solution container through a gas inlet 100 and exits via a gas outlet 101 carrying away the evaporated water. The exhaust gas flow is illustrated by the solid arrows, the dashed arrows illustrating the effluents flow and the dashed/dotted arrows the air flow.

The exhaust gases coming back from the conversion unit 17 could be provided to a heat exchanger that heats an air stream coming from the environment and heats the precursor through the tubular heater 18 and the vapor dome of the tank through the gas inlet 100 and the gas outlet 101.

Figure 12 illustrates schematically an alternative to the previous embodiment of a device according to the invention for increasing the urea concentration of a first urea solution. This embodiment differs from the device disclosed in fig. 11 in that the urea solution reservoir 102 is provided with a bubbling system, preferably a micro-bubbling system 1001. Here, a part of the exhaust gas carrying the residual heat is used to heat up a tubular heating element 18 inside the urea solution reservoir 102 and the other part of the exhaust gas is provided to the urea solution reservoir 102 through a bubbling system, preferably a micro-bubbling system 1001. The gas bubbles travel from the bottom of the urea solution container 102 to the top supplying the heat for evaporation and carrying away the evaporated moisture from the urea solution. Such a bubbling system, preferably a micro-bubbling system 1001, enhances the evaporation. The exhaust gas flow is illustrated by the solid arrows, the dashed arrows illustrating the effluents flow.

Figure 13 illustrates schematically an embodiment of a device 1 according to the invention for increasing the urea concentration of a first urea solution. The device 1 comprises a urea solution container 10, said urea solution container 10 comprising a gas inlet 100 and a gas outlet 101, said urea solution container being a first urea solution reservoir 102. The first urea solution reservoir 102 is provided with a tubular heating element 18. The device 1 comprises also a fuel cell 12 having a cathode side and an anode side. The fuel cell 12 is connected to a fuel cracker 19 comprising a combustion chamber 190. The fuel cracker 19 is connected to a conversion unit 17 comprising a jacketed device 170. The conversion unit is connected to the first urea solution reservoir 102.

Here, the heated gas coming from the anode side of the fuel cell 12 is used as a fuel in the combustion chamber 190 of the cracker device 19, said exhaust gas having a temperature around 80°C. It should be noted that part of the stream

coming out of the periphery cracker can be directly recycled to the center of the cracker without being cooled down at 80°C. The cracker operates around 600°C.

The combustion chamber 190 heats up the fuel cracker device 19 where  
5 the fuel coming out of the conversion unit 17 is converted into fuel ready to feed the fuel cell 12. The heated gas coming from the cracker device 19 at a temperature of about 600°C heats up the conversion unit 17. The conversion unit 17 is a jacketed device 170 where the fuel precursor is converted into fuel ready to feed the cracker device 19. The hot gases, after having travelled through the  
10 conversion unit 17, heats up the tubular heating 18 inside the urea solution reservoir 102. The tubular heater 18 thaws or warms up the urea solution generating liquid flow and fresh air flow from the environment enters the urea solution container through the gas inlet 100 and exits via the gas outlet 101 removing the evaporated water. The gas flow, after passing through the  
15 conversion unit 17, can be used as described in figures 10 and 12. The exhaust gas flow is illustrated by the solid arrows, the dashed arrows illustrating the effluents flow and solid arrows the air flow.

The low urea concentration of commercial solution has an impact on the driving range of a vehicle. Progressive water removal and concentration of  
20 the urea solution allows earlier refilling of the tank, which increases the driving range. For example, 140 liters tank of Adblue® (urea 32.5 weight %) is typically required to feed a fuel cell for a drive range of 500 km. If this solution is concentrated to urea 55% by removing 57 liters of water, another 57 liters of AdBlue® can be filled into the tank, increasing the drive range by adding another  
25 200 Km of autonomy. In addition, the removal of water offers other advantages: first, the total energetic efficiency of the urea is increased for the ammonia conversion (SCR) or urea to power chain (Fuel cell). Secondly, the average total weight of reducing agent solution or fuel precursor needed on the vehicle for a given range is reduced, what is favorable to total power consumption on a vehicle.

During the conversion of Adblue® using the method and the device according to the invention 30% of the energy is used the heat the liquid to the reaction temperature (250°C), 32% of the energy is used for the conversion reaction (effluents in gaseous form), and 38% of the energy is used for water  
5 evaporation.

In comparison with an amount of urea solution with a weight concentration of urea of 55% and for the same urea content, the amount of energy used for heating the liquid is divided with between 1,5 and 4, the amount of energy required for the process being about the same, and the amount of energy  
10 used for evaporation is divided with between 1.5 and 4.

Thus, the usage of the water removal method according to the invention, enables a reduction of energy consumption by a factor of between 1,1 and 2,61,.

Thus the tout amount of energy required for obtain the same  
15 concentration is divided with a factor 1,7 when using the method and device according to the invention in computation to the usage of a urea solution with a weight concentration of urea of 55%

## REVENDICATIONS

1. Method for increasing the urea concentration of a urea solution in a container (10, 102, 104) on board of a vehicle, preferably a moving vehicle, said method comprising the steps of:
  - a) providing a first gas flow above a first urea solution (11) and/or blowing a second gas in the first urea solution (11),
  - b) Obtaining a second urea solution the urea concentration of the second urea solution being higher than the urea concentration of the first urea solution.
2. Method for increasing the urea concentration of a urea solution in a container (10, 102, 104) on board of a vehicle according to any one of claim 1, wherein the first gas and/or the second gas is selected from the group consisting of air, exhaust gas and their mixtures.
3. Method for increasing the urea concentration of a urea solution in a container (10, 102, 104) on board of a vehicle according to any one of the preceding claims, wherein the first gas and the second gas are identical.
4. Method for increasing the urea concentration of a urea solution in a container on board of a vehicle according to any one of the preceding claims, wherein the first gas and second gas of step a) have a temperature comprised in the range of 0°C to 600°C, preferably in the range of 10°C to 200°C, most preferably in the range of 15 °C to 100°C.
5. Method for increasing the urea concentration of a urea solution in a container on board of a vehicle according to any one of the preceding claims, comprising a step c) of adding a third urea solution to the second urea solution.
6. Method for increasing the urea concentration of a urea solution

in a container (10, 102, 104) on board of a vehicle according to 5, wherein the urea concentration of the third urea solution is equal or lower than the urea concentration of the second urea solution.

7. Device 1 for increasing a urea concentration of a urea solution  
5 in a vehicle, said device 1 comprising a urea solution container (10, 102, 104) characterized in that said urea solution container comprises a gas inlet (100) and a gas outlet (101), said gas outlet being located above the level of the urea solution in said container.

8. Device 1 for increasing a urea concentration of a urea solution  
10 in a vehicle according to claim 7, wherein said urea solution container (10,102, 104) comprises a means (103) for increasing solvent evaporation.

9. Device (1) for increasing the urea concentration of a urea solution in a vehicle according to claim 8, wherein the means for increasing solvent evaporation comprises capillarity enhancer means (1031).

15 10. Device (1) for increasing the urea concentration of a urea solution in a vehicle according to any of claims 8 to 9, wherein the capillarity enhancer means (1031) is fixed on said urea solution container and/or floating on the surface of the first urea solution.

11. Device (1) for increasing the urea concentration of a urea  
20 solution in a vehicle according to any one of the preceding claims, wherein the gas inlet is located above and/or under the level of the urea solution in said urea solution container.

12. Device (1) for increasing the urea concentration of a urea solution in a vehicle according to any one of the preceding claims, wherein said  
25 urea solution container comprises a plurality of gas inlets (100).

13. Device (1) for increasing the urea concentration of a urea solution in a vehicle according to any one of the preceding claims, wherein said

urea solution container comprises a plurality of gas outlets (101).

**14.** Device (1) for increasing the urea concentration of a urea solution in a vehicle according to any one of the preceding claims, wherein said urea solution container comprises a heater.

5                   **15.** Vehicle system comprising a device (1) for increasing the urea concentration of a urea solution in a vehicle according to any one of claims 7 to 14.

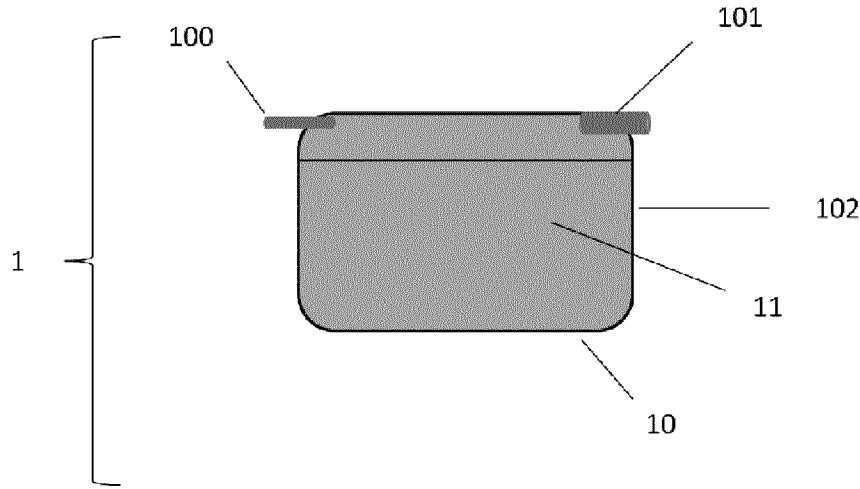


Fig. 1

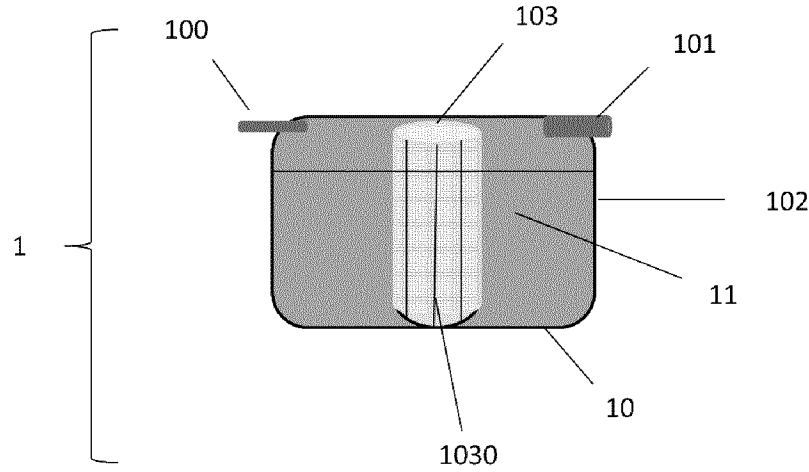


Fig. 2

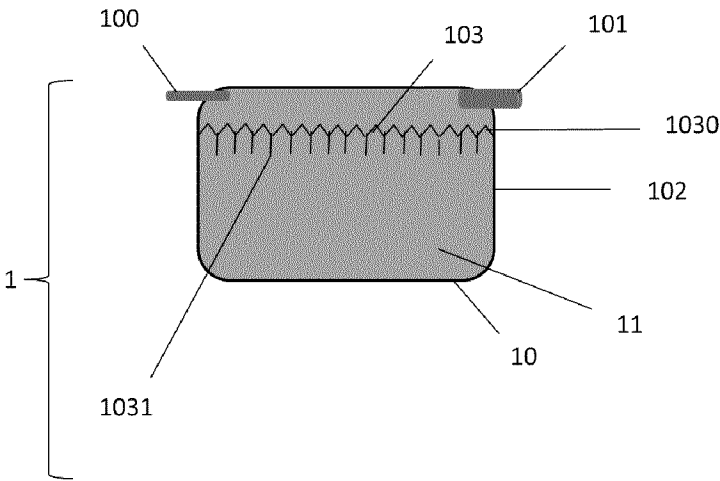


Fig. 3

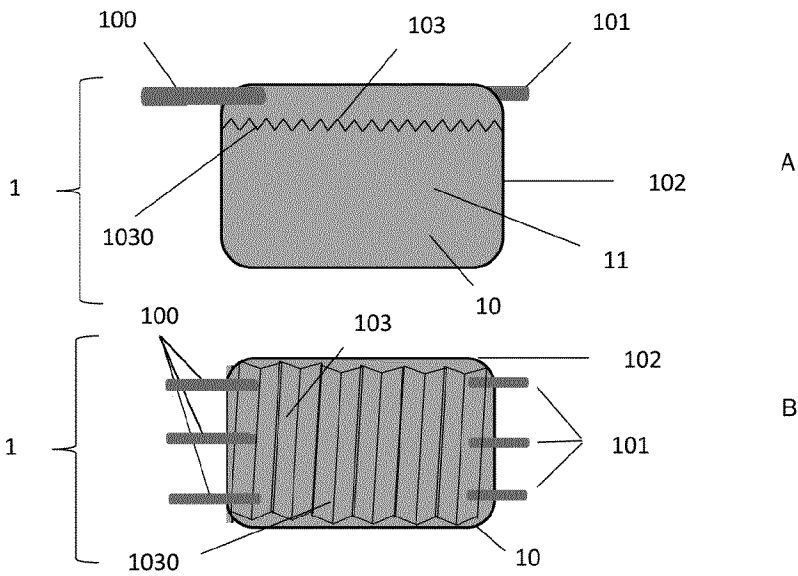


Fig 4

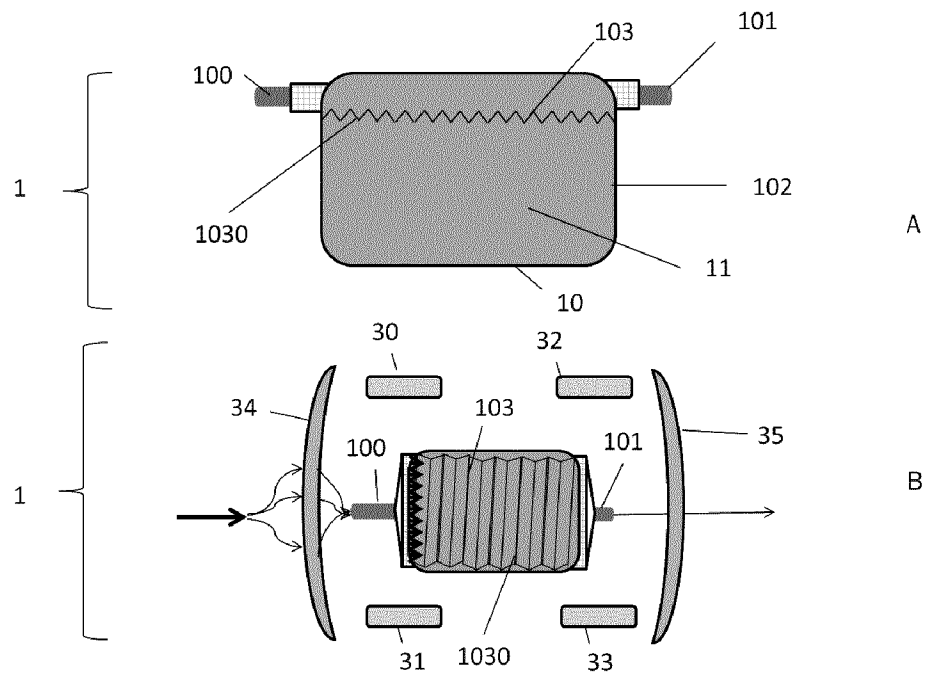


Fig. 5

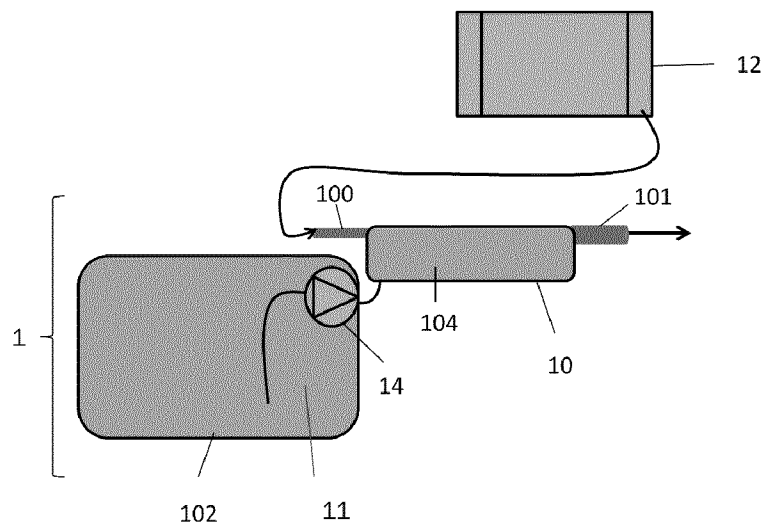


Fig. 6

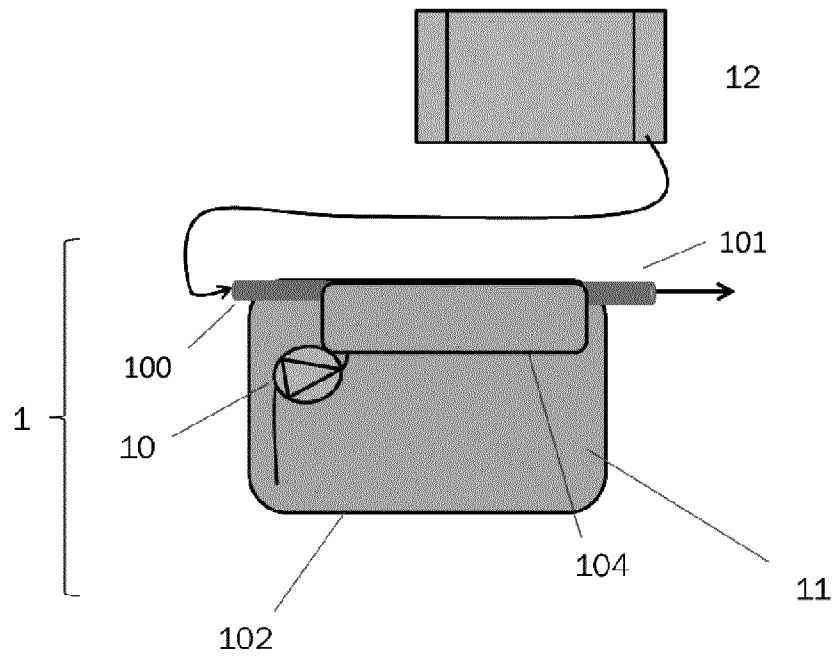


Fig. 7

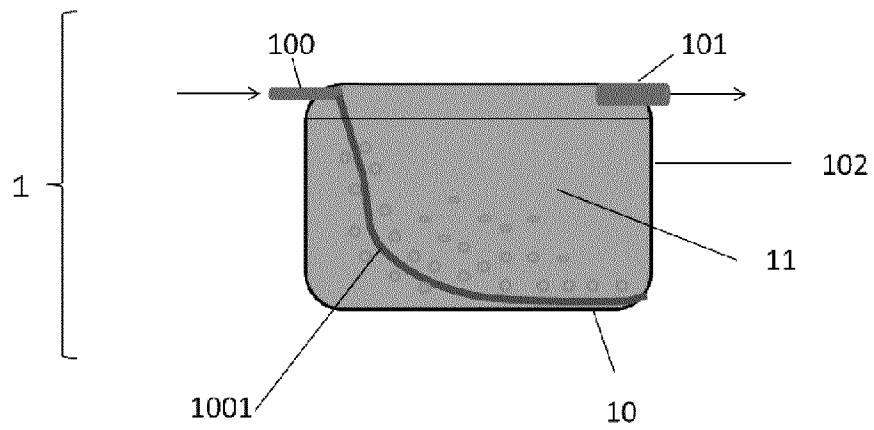


Fig. 8

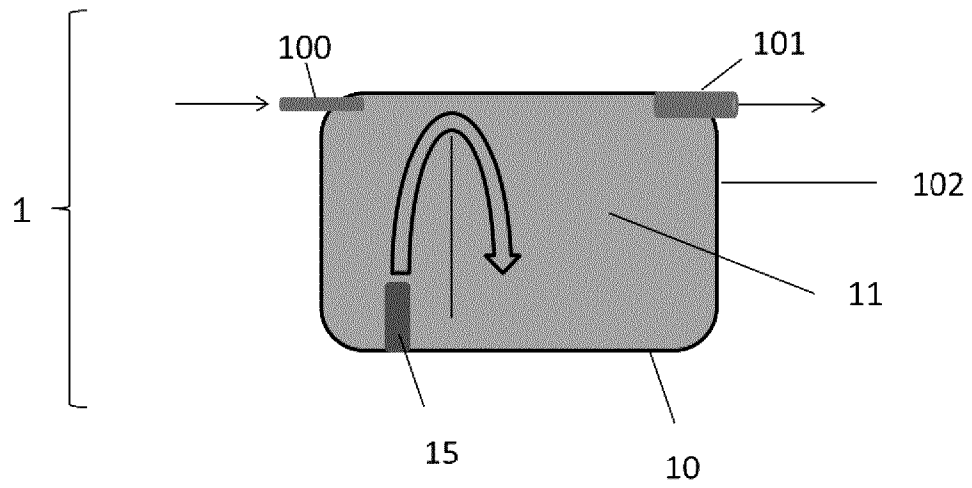


Fig. 9

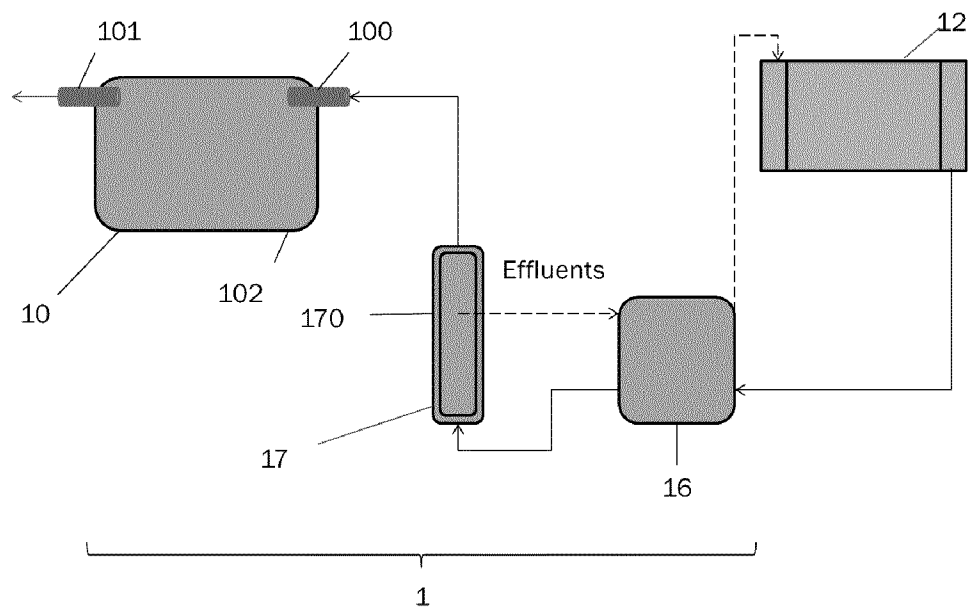


Fig. 10

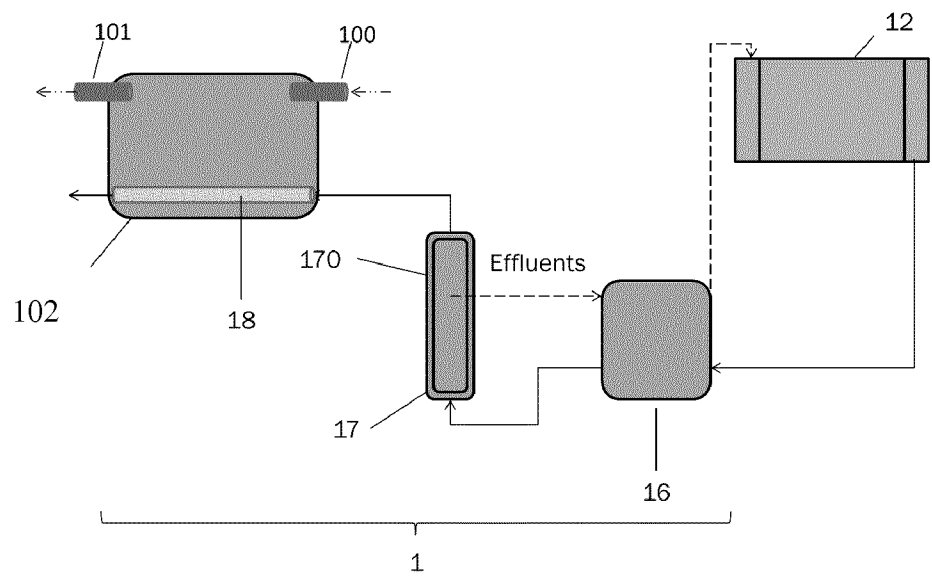


Fig. 11

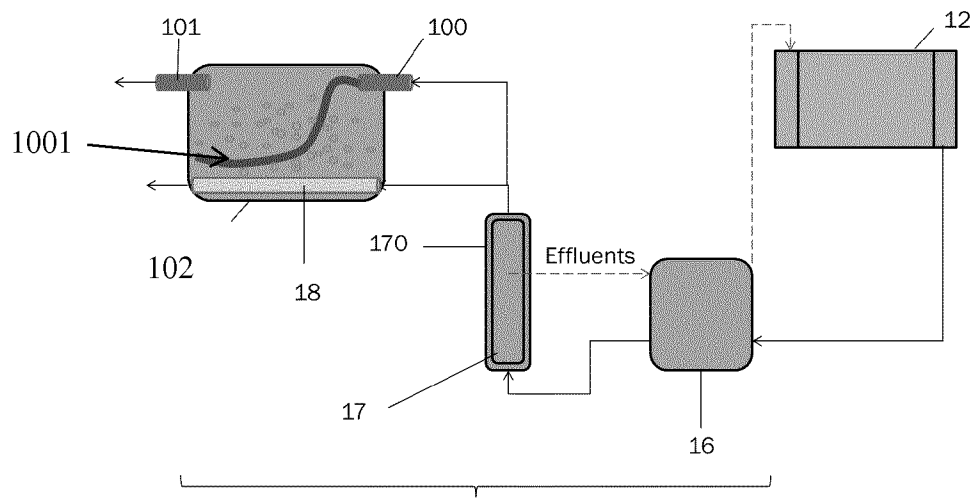


Fig. 12

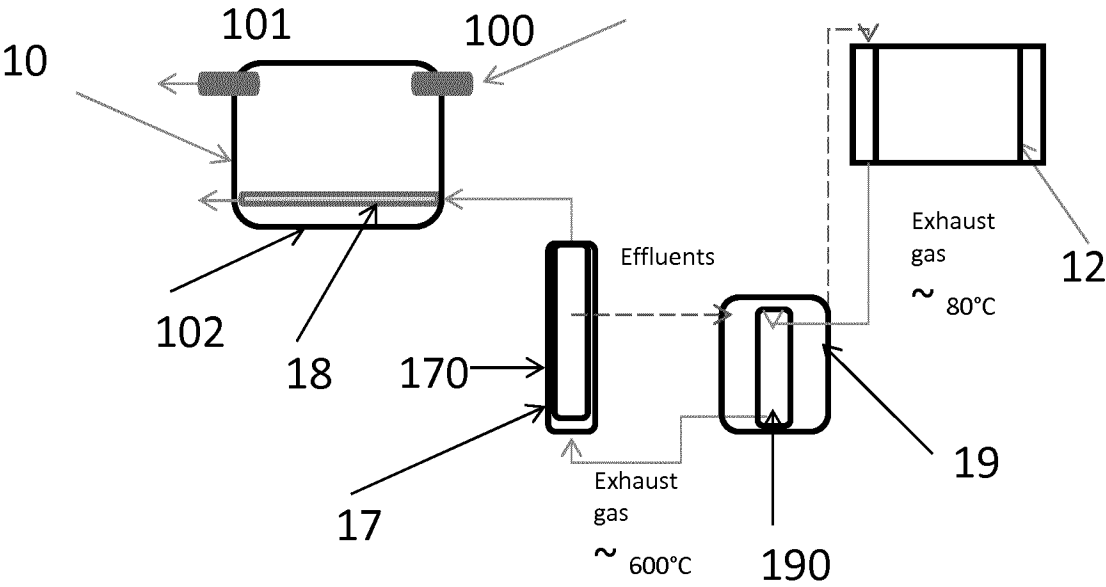


Fig. 13

## INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2018/073722

A. CLASSIFICATION OF SUBJECT MATTER  
 INV. F01N3/20  
 ADD.

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)  
 F01N

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 practicable, search terms used)

EPO-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                         | Relevant to claim No. |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | JP S57 171956 A (TOYO ENGINEERING CORP;<br>MITSUI TOATSU CHEMICALS)<br>22 October 1982 (1982-10-22)<br>cited in the application<br>abstract<br>figures 2,3 | 7,8,11,<br>14         |
| A         | DE 10 2014 119443 A1 (HYUNDAI MOTOR CO LTD<br>[KR]) 15 October 2015 (2015-10-15)<br>figure 8                                                               | 1-15                  |
| A         | EP 2 927 039 A1 (INERGY AUTOMOTIVE SYSTEMS<br>RES [BE]) 7 October 2015 (2015-10-07)<br>figure 3                                                            | 1-15                  |



Further documents are listed in the continuation of Box C.



See patent family annex.

## \* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

5 October 2018

Date of mailing of the international search report

18/10/2018

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2  
 NL - 2280 HV Rijswijk  
 Tel. (+31-70) 340-2040,  
 Fax: (+31-70) 340-3016

Authorized officer

Wagner, A

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2018/073722

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
|-------------------------------------------|---------------------|----------------------------|---------------------|
| JP S57171956 A                            | 22-10-1982          | NONE                       |                     |
| -----                                     |                     |                            |                     |
| DE 102014119443 A1                        | 15-10-2015          | CN 104971624 A             | 14-10-2015          |
|                                           |                     | DE 102014119443 A1         | 15-10-2015          |
|                                           |                     | KR 20150117814 A           | 21-10-2015          |
|                                           |                     | US 2015290586 A1           | 15-10-2015          |
| -----                                     |                     |                            |                     |
| EP 2927039 A1                             | 07-10-2015          | CN 106164459 A             | 23-11-2016          |
|                                           |                     | EP 2927039 A1              | 07-10-2015          |
|                                           |                     | US 2017174072 A1           | 22-06-2017          |
|                                           |                     | WO 2015150025 A1           | 08-10-2015          |
| -----                                     |                     |                            |                     |