A method for operating an evaporation unit for converting a volume flow to an ammonia-containing gas flow includes providing the evaporator unit with at least one first section and a second section downstream of the first section. The volume flow flows through the sections for evaporation. The volume flow is heated to not more than 180°C in the first section by supplying a first amount of heat energy and the volume flow is heated to more than 350°C and completely evaporated in the second section. A motor vehicle having an evaporation unit is also provided.
METHOD FOR OPERATING AN EVAPORATION UNIT FOR PRODUCING GASEOUS AMMONIA AND MOTOR VEHICLE HAVING AN EVAPORATION UNIT

CROSS-REFERENCE TO RELATED APPLICATION

This is a continuation, under 35 U.S.C. §120, of copending International Application No. PCT/EP2009/062629, filed Sep. 29, 2009, which designated the United States; this application also claims the priority, under 35 U.S.C. §119, of German Patent Application DE 10 2008 051 168.4, filed Oct. 10, 2008; the prior applications are herewith incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method for operating an evaporation unit for producing a gas flow containing ammonia. Such an evaporation unit is used, in particular, for providing gaseous ammonia from an ammonia precursor, in particular in liquid and/or solid form. The invention also relates to a motor vehicle having an evaporation unit which is used, in particular, within the context of exhaust-gas aftertreatment.

In diesel internal combustion engines in particular, it has proven to be expedient for urea in aqueous solution to be added directly to the exhaust gas produced by the internal combustion engine, or for ammonia to be added to the exhaust gas after a hydrolysis carried out outside the exhaust gas. In that case, in known methods, use is made of a hydrolysis catalytic converter in which ammonia is obtained from the urea. The aqueous urea solution is metered in upstream of the hydrolysis catalytic converter, is changed into a gaseous state and is brought into contact with the hydrolysis catalytic converter. The ammonia which is generated in that way then reacts, for example with a so-called SCR catalytic converter further downstream in the exhaust-gas flow, with the nitrogen oxides contained therein to form molecular nitrogen and water.

Temperature control is particularly difficult during the evaporation of the aqueous urea solution. In that case, it must be taken into consideration that firstly the required quantities of the urea solution and secondly the available temperatures can vary significantly during a mobile application. If only incomplete evaporation is obtained, intermediate products may form, which can possibly lead to the evaporator unit becoming blocked. Such undesired by-products are, for example, water-insoluble biuret, which is formed from isocyanic acid and urea, and cyanuric acid, which is the trimerization product of the isocyanic acid. During the evaporation of an ammonia precursor, in particular of a liquid urea-water solution, it has been observed that the introduction of temperature into the liquid must take place very quickly over a critical temperature range in order to prevent the formation of those undesired, partially no longer removable compounds.

Devices have already been described for the evaporation, outside the exhaust gas, of a urea-water solution, but those devices have heretofore being unconvincing at least for use in the automotive field. In that case, the known evaporation devices in part cannot guarantee the desired completeness of evaporation over all operating states and/or quantities of the ammonia precursor to be evaporated. That applies, in particular, in the event of highly dynamic regulation of the evaporation unit taking into consideration operating states of a mobile internal combustion engine, such as for example a diesel engine.

SUMMARY OF THE INVENTION

It is accordingly an object of the invention to provide a method for operating an evaporation unit for producing gaseous ammonia and a motor vehicle having an evaporation unit, which overcome the hereinafore-mentioned disadvantages and at least partially solve the highlighted problems of the heretofore-known methods and vehicles of this general type. In particular, it is sought to specify a method for operating an evaporation unit which permits a fast and complete evaporation of a urea-water solution to produce a gas flow containing ammonia. The evaporation unit operated through the use of such a method can thereby provide ammonia in precisely predefined quantities in a highly dynamic manner.

With the foregoing and other objects in view there is provided, in accordance with the invention, a method for operating an evaporation unit for converting a volume flow into an ammonia-containing gas flow. The method comprises providing the evaporation unit with at least a first section and a second section downstream of the first section in flow direction of the volume flow, conducting the volume flow through the first and second sections for evaporating the volume flow, heating the volume flow to at most 180°C. by supplying a first amount of heat energy in the first section, heating the volume flow to over 350°C. and completely evaporating the volume flow by supplying a second amount of heat energy in a partial region of the second section, and adjusting or regulating the second amount of heat energy to be greater than the first amount of heat energy.

An evaporation unit suitable for the method according to the invention preferably has a very compact construction and, for example, a tubular form. The external dimensions of such an evaporation unit are, for example, a length of approximately 400 mm and a diameter in the range of 50 mm. The evaporation unit is therefore suitable, in particular, for being part of a line section of an exhaust system of a mobile internal combustion engine, and/or part of a line section of an auxiliary secondary system which opens into the exhaust line. An evaporation unit which is particularly suitable for the method according to the invention is disclosed in German Published Application DE 10 2008 023 938 A1, corresponding to U.S. Patent Application Publication Nos. 2011/0041484 A1 and 2011/0023470 A1, the entire content of the disclosure of which is incorporated herein by reference. In that case, the first and second sections of the present invention respectively correspond to the first and second evaporation sections in German Published Application DE 10 2008 023 938 A1 and U.S. Patent Application Publication Nos. 2011/0041484 A1 and 2011/0023470 A1.

The evaporation unit which is suitable for the method according to the invention has, in particular, at least one flow duct which extends at least through the first and second sections, wherein at least one heating element extends along the flow duct in order to heat the volume flow, in particular of a liquid (water-containing) urea solution, in a targeted and regulated manner.

A significant proportion of the volume flow (in particular an aqueous urea solution) supplied to the evaporation unit is evaporated already in the first section. It is possible, for example, for at least 20 wt. %, preferably at least 30 wt. % of
the volume flow to be evaporated already in the first section. That proportion should, however, be no greater than 50 wt. %. For this purpose, heating to at least 100 °C, preferably to at least 135 °C, particularly preferably to at least 150 °C, but at most to 180 °C, should take place in the first section. In this case, self-regulating PTC (positive temperature coefficient) elements as active heating elements may preferably be used in the region of the first section. The PTC elements are current-conducting materials which can conduct the current better at lower temperatures than at high temperatures. The electrical resistance increases with rising temperature. This also means in other words that the heating power likewise becomes lower with rising temperature. It is only in the second section of the evaporation unit that the volume flow is heated further, in particular through the use of the at least one heating element, and for the most part, preferably completely, evaporated. In this case, the second section is divided at least into a first partial region and a remaining region, wherein mutually independent amounts of heat energy can preferably be supplied to the volume flow in the first partial region and in the remaining region.

[0011] In summary, it is proposed herein that (at least) two-stage evaporation be carried out, by virtue of a part of the volume flow being evaporated with a relatively low amount of heat energy in a first section, and the remainder of the volume flow being evaporated with an increased amount of heat energy in (a directly following) second section. In this way, it is for example possible to prevent steam cushions from forming in the first section which prevent a complete evaporation over a short evaporation path.

[0012] In one advantageous embodiment of the method, the second amount of heat energy supplied in the partial region is also greater than the amount of heat energy supplied in the remaining region of the second section. An increase of the amount of heat energy may be made possible, in particular, through the use of suitable configurations of the at least one heating element. For example, a close or tight winding or coil of the heating element may be disposed in the region of the first partial region or the heating element may be disposed directly at the flow duct or channel. Furthermore, additional heating elements may be provided which permit the introduction of an increased amount of heat energy in relation to the first section and to the remaining region of the second section.

[0013] In accordance with another mode of the invention, a second amount of heat energy is provided through the use of the method. The second amount of heat energy is at least twice as great as the first amount of heat energy and/or twice as great as a third amount of heat energy supplied in the remaining region.

[0014] In this case, it is, in particular, also preferable for the heating power to be equal in each case, if appropriate.

[0015] Furthermore, it is, if appropriate, also considered to be advantageous for the heating elements in the two sections to be heated with the same cycle times or clock cycles, wherein the amount of heat energy in the second section is fixed as a function of the present mass flow of urea, or the mass flow of urea to be evaporated, and the amount of heat energy in the second section is regulated to be less than 50%, preferably approximately 30%, of the amount of heat energy in the second section.

[0016] It is advantageously the case that, through the use of corresponding amounts of heat energy, the volume flow is heated to over 350 °C and completely evaporated already in the partial region.

[0017] In this regard, it is preferable for the partial region to be disposed directly at an inlet of the second section. It has, however, proven in this case to be particularly advantageous for the greatest amount of heat energy to be introduced in the entry region of the actual evaporation section. Accordingly, in a preferred embodiment of the method, the first partial region is disposed directly at the start of the second section. As a result of the introduction of the greatest amount of heat energy in that locally restricted partial region, it is possible to ensure reliable complete evaporation, in particular of a urea-water solution.

[0018] In a preferred embodiment of the method, the partial region has a length of at most 150 mm in the case of a volume flow of at most 100 ml/min. The partial region has, in particular, a length of at most 50 mm. In this case, evaporation units are to be assumed, in particular, to have a component length of 400 mm.

[0019] In particular, the first partial region extends at most over one third of the total length of the second section, in particular over a length of at most 50 mm, in the case of a volume flow of at most 70 ml/min.

[0020] Through the use of such a configuration of the method, a reliable, complete evaporation is obtained, in particular, of an aqueous urea solution obtained, in such a way that no by-products can contaminate and/or impair the function of the evaporation unit.

[0021] In a further advantageous embodiment, at least one temperature sensor is provided at least in the first partial region. In this case, multi-point temperature measurement points are preferably provided which are disposed at different points within a housing of the evaporation unit and which, for a certain region of the evaporation unit, yield a temperature value to be integrated.

[0022] It should be observed, in particular, that the amount of heat energy or the temperature of the heating element to be set is regulated as a function of the volume flow of the urea-water solution. In particular, a lower temperature of the heating element and a lower amount of heat energy should be provided in the case of a small volume flow than in the case of a relatively large volume flow.

[0023] With the objects of the invention in view, there is concomitantly provided a motor vehicle, comprising an internal combustion engine and an exhaust system associated with the internal combustion engine. The exhaust system has at least one SCR catalytic converter body and at least one port or connection disposed between the internal combustion engine and the at least one SCR catalytic converter body. An evaporation unit is disposed at the at least one port for conducting a flow of gaseous ammonia into the exhaust system and to the at least one SCR catalytic converter body. A controller is connected to the evaporation unit and configured or programmed to at least regulate the second amount of heat energy, in particular also the first amount of heat energy and/or the third amount of heat energy, for carrying out the method according to the invention.

[0024] A (ceramic, extruded) honeycomb body which has, for example, an SCR coating, is conventionally used as the SCR catalytic converter body. An SCR coating of that type is preferably of the \( \text{V}_2\text{O}_5/\text{WO}_3/\text{TiO}_2 \) type (vanadium pentoxide/tungsten trioxide/titanium dioxide).

[0025] Other features which are considered as characteristic for the invention are set forth in the appended claims, noting that the features specified individually in the depen-
dent claims can be combined with one another in any desired technologically meaningful way and present further embodiments of the invention.

Although the invention is illustrated and described herein as embodied in a method for operating an evaporation unit for producing gaseous ammonia and a motor vehicle having an evaporation unit, it is nevertheless not intended to be limited to the details shown, since various modifications and structural changes may be made therein without departing from the spirit of the invention and within the scope and range of equivalents of the claims.

The construction and method of operation of the invention, however, together with additional objects and advantages thereof will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. 1 is a diagrammatic, longitudinal-sectional view of a structural variant of an evaporation unit suitable for carrying out the method according to the invention; and

FIG. 2 is a plan view of a motor vehicle illustrating the structure of an SCR system.

DETAILED DESCRIPTION OF THE INVENTION

Referring now in detail to the figures of the drawing, in which the same reference numerals are used for identical objects for explaining the invention and the technical field in more detail by showing particularly preferred structural variants to which the invention is not restricted, and first, particularly, to FIG. 1 thereof, there is seen a sectional view of a first particularly preferred structural variant of an evaporation unit 1 which is suitable for carrying out the method according to the invention. The evaporation unit 1 is delimited toward the outside by a housing 34. The evaporation unit 1 can be divided into at least two (2) partial regions, specifically a first section 4 and a second section 5, in a flow direction 28 of a volume flow 2 (for example a urea-water solution) to be evaporated.

The central component of the evaporation unit 1 is a centrally disposed flow duct or channel 33. In this case, a urea-water solution, in particular, enters in liquid form in the flow direction 28 and then passes through the first section 4 as a volume flow 2. In this case, the volume flow 2 is heated and partially evaporated by at least one first heating element 29 through the use of a first amount of heat energy 6.

The volume flow 2, which is preheated in the first section 4, enters through an inlet 10 into the second section 5 of the evaporation unit 1. In this embodiment, a partial region 7 is disposed directly downstream of the inlet 10. A high second amount of heat energy 9 is supplied in the partial region 7, as a result of which the volume flow 2 is at least for the most part, preferably completely, evaporated and heated to over 350° C. A second heating element 30 is preferably provided for producing the second amount of heat energy 9. It is, however, also possible for the partial region 9 to be heated through the use of the first heating element 29 and/or through the use of a third heating element 31 which is provided, in particular, in addition to the first heating element 29 and/or in addition to the second heating element 30. The first, second and third heating elements (29, 30, 31) have, in particular, separate terminals in each case for energy supply. In this case, the partial region 7 extends with a length 11 only over a part of a total length 12 of the second section 5. The volume flow 2, which is at least partially evaporated in this case, is heated further, and in particular completely evaporated, in a remaining region 8 of the second section 5, in such a way that the volume flow 2, after passing through at least the first section 4 and the second section 5, exits the evaporation unit 1 as a gas flow 3.

The evaporation unit 1 has, at least in the partial region 7, temperature sensors 13 which permit measurement and corresponding control of the amount of heat energy and of the temperature used in the method according to the invention. It is very particularly preferable for the temperature sensors to be disposed in such a way that a first temperature sensor is disposed in an end region of the first section and a second temperature sensor is disposed in an entry region of the second section, in such a way that a distance of preferably at most 20 mm, in particular at most 10 mm, is present between the two temperature sensors. In this case, it is sought to monitor and/or control, in particular, a temperature increase between the temperature sensors from approximately 180° C. (first limit temperature) to approximately 300° C. (second limit temperature).

The evaporation unit 1 may have a widening in an end region 35 of the flow duct 33, into which the heretofore completely evaporated urea-hydrogen solution expands. A reactor chamber, in which a honeycomb body having a hydrolysis coating is provided, preferably adjoining the widening. The gas which has been converted completely to ammonia then exits the evaporation unit 1 and can flow into an exhaust system 20 shown in FIG. 2.

FIG. 2 diagrammatically shows a motor vehicle 18, in particular a passenger motor vehicle or a utility motor vehicle. Exhaust gas generated in an internal combustion engine 19 is purified through the use of the corresponding exhaust system 20 and released into the environment. In this case, the exhaust gas flows in the flow direction 28 firstly through a catalytic converter 24 (for example an oxidation catalytic converter) before finally arriving at an SCR catalytic converter body 21 further downstream. A port or connection 22 for an evaporation unit 1 is provided between the catalytic converter 24 and the SCR catalytic converter body 21, in such a way that the gas flow 3 containing ammonia can be introduced at the port 22. The exhaust-gas flow laden with ammonia then arrives, if appropriate, at a flow manipulator 25 (for example a static mixer) before the mixture reaches the SCR catalytic converter body 21. For completeness, it is pointed out herein that the SCR catalytic converter 21 may be provided with further exhaust-gas treatment components in an inlet region 26 and/or in an outlet region 27, such as, for example, a particle separator in the inlet region 26 and/or an oxidation catalytic converter in the outlet region 27. It is likewise pointed out that other exhaust-gas treatment devices may also be provided in the exhaust system 20.

The evaporation unit 1 is connected through a plurality of line sections 17 to a reservoir 15. A liquid urea-water solution, which is provided in the reservoir 15, for example, is then supplied, at appropriate times and/or in appropriate volumes, to the evaporation unit 1 through the use of a dosing pump 16. For this purpose, the dosing pump 16, the evaporation unit 1 and/or the internal combustion engine 19 may be connected (in data-transmitting fashion and/or operatively) to a controller 23 in order to ensure controlled admixture of urea-water solution to the evaporation unit 1 and of ammonia gas to the exhaust gas in this case.
Merely for the sake of completeness, it is also pointed out herein that a device 14 including at least one reservoir 15, a line section 17, a dosing pump 16 and an evaporation unit 1, may also be marketed separately in any desired quantities as a component set with or without a controller 23.

1. A method for operating an evaporation unit for converting a volume flow into an ammonia-containing gas flow, the method comprising the following steps:
   providing the evaporation unit with at least a first section and a second section downstream of the first section in flow direction of the volume flow;
   conducting the volume flow through the first and second sections for evaporating the volume flow;
   heating the volume flow to at most 180° C. by supplying a first amount of heat energy in the first section;
   heating the volume flow to over 350° C. and completely evaporating the volume flow by supplying a second amount of heat energy in a partial region of the second section; and
   adjusting the second amount of heat energy to be greater than the first amount of heat energy.

2. The method according to claim 1, wherein the second amount of heat energy is at least twice as large as the first amount of heat energy.

3. The method according to claim 1, which further comprises heating the volume flow to over 350° C. and completely evaporating the volume flow in the partial region.

4. The method according to claim 1, which further comprises placing the partial region directly at an inlet of the second section.

5. The method according to claim 1, which further comprises providing the partial region with a length of at most 150 mm, for a volume flow of at most 100 ml/min.

6. The method according to claim 1, which further comprises providing the partial region with a length of at most one third of a total length of the second section, for a volume flow of at most 70 ml/min.

7. The method according to claim 1, which further comprises regulating at least the second amount of heat energy as a function of the volume flow with at least one temperature sensor disposed at least in the partial region.

8. A motor vehicle, comprising:
   an internal combustion engine;
   an exhaust system associated with said internal combustion engine, said exhaust system having at least one SCR catalytic converter body and at least one port disposed between said internal combustion engine and said at least one SCR catalytic converter body;
   an evaporation unit disposed at said at least one port for conducting a flow of gaseous ammonia into said exhaust system and to said at least one SCR catalytic converter body; and
   a controller connected to said evaporation unit and configured to at least regulate the second amount of heat energy for carrying out the method according to claim 1.

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