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APPARATUS FOR EVAPORATING A UREA-WATER SOLUTION

Abstract of the Invention

A device (1) for evaporating a urea-water solution, having a delivery duct (2) for the urea-water solution, said delivery duct extending through at least a first zone (3) and a second zone (4) for the introduction of heat energy, wherein the zones can be heated separately from one another, and, in the second zone (4), the delivery duct (2) initially has a meandering profile (7) in a second inlet region (6), and thereafter has a rectilinear profile (8). Also proposed is a method in which the urea-water solution is pre-heated in the first zone (3) to a temperature in the range from 100°C to 150°C, and is evaporated in the second zone (4) at a temperature in the range from 420°C to 490°C. In particular, the tendency for such an exhaust-gas-external evaporator for a urea-water solution to become blocked is significantly reduced in this way.

Fig. 1

We Claim:

1. A device (1) for evaporating a urea-water solution, having a delivery duct (2) for the urea-water solution, said delivery duct extending through at least a first zone (3) and a second zone (4) for the introduction of heat energy, wherein the zones can be heated separately from one another, and, in the second zone (4), the delivery duct (2) initially has a meandering profile (7) in a second inlet region (6), and thereafter has a rectilinear profile (8).

2. The device (1) as claimed in patent claim 1, in which, in the second zone (4), the delivery duct (2) has a meandering profile (6) in a second outlet region (8).

3. The device (1) as claimed in patent claim 1 or 2, in which, in a transition zone (9) from the first zone (3) to the second zone (4), the delivery duct (2) is formed with an enlarged cross section (10).

4. The device (1) as claimed in one of the preceding claims, in which, in the first zone (4), the delivery duct (2) initially has a rectilinear profile (7) in a first inlet region (11), and thereafter has a meandering profile (6).

5. The device as claimed in one of the preceding patent claims, in which the first zone (3) and the second zone (4) are connected by means of a tube (12) which surrounds the delivery duct (2).

6. The device (1) as claimed in one of the preceding patent claims, in which the delivery duct (2) is formed with a capillary (13) which is arranged so as to be in heat-conducting contact with at least one electric heating element (14).

7. A method for operating a device (1) as claimed in one of the preceding patent claims, in which the urea-water solution is pre-heated in the first zone (3) to a

temperature in the range from 100°C to 180°C, and is evaporated in the second zone (4) at a temperature in the range from 420°C to 490°C.

8. The method as claimed in the preceding patent claim, in which the urea-water solution is operated with a throughput of down to 10 ml/min.

9. A motor vehicle (15) having a controller (16) and having an exhaust system (17) with a reducing agent metering system (18), wherein the reducing agent metering system (18) has at least one device (1) as claimed in one of patent claims 1 to 6, and the controller (16) is set up to carry out the method for an intermittent metered addition of reducing agent.

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LEX ORBIS IP PRACTICE

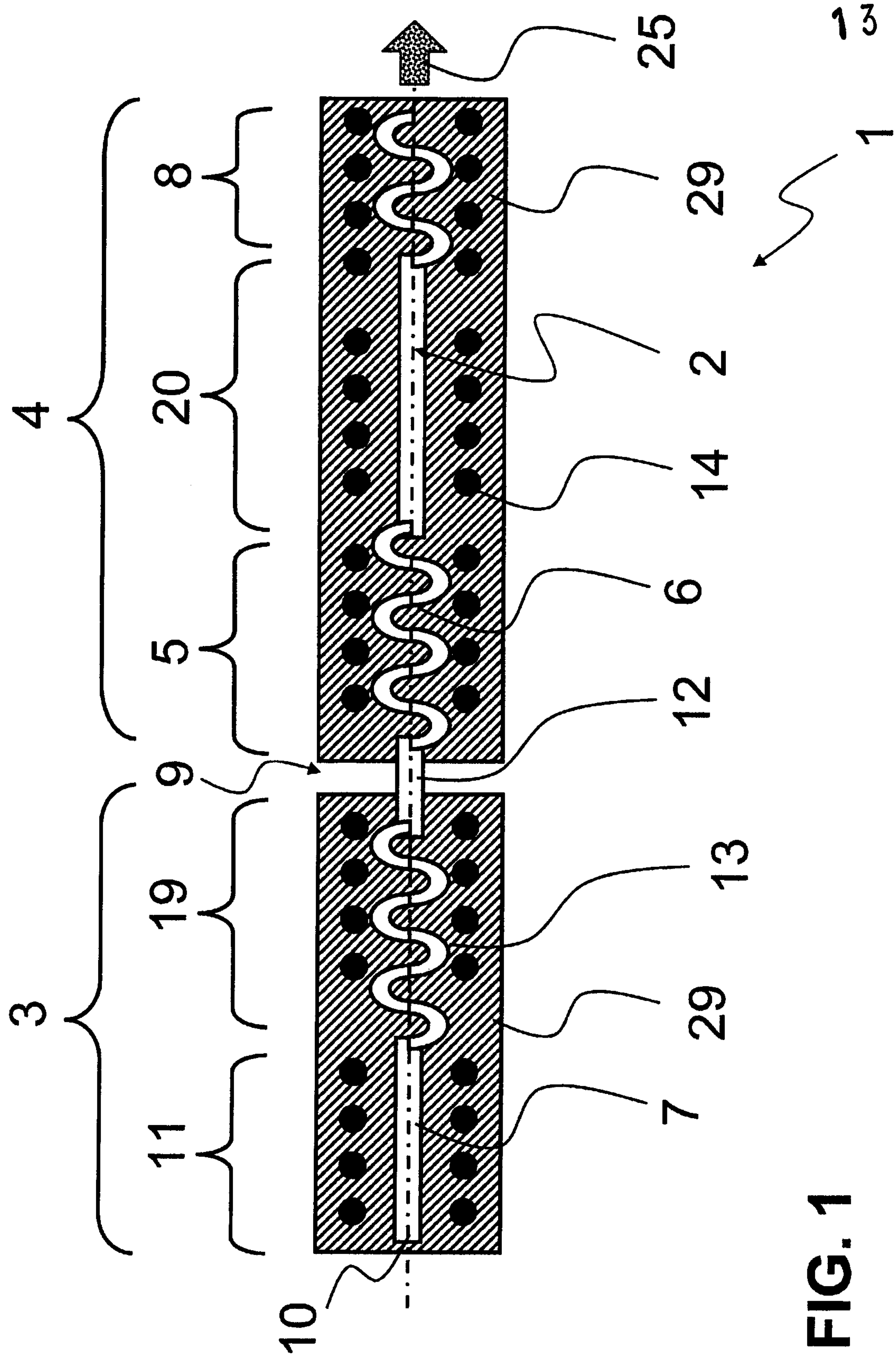

FIG. 1

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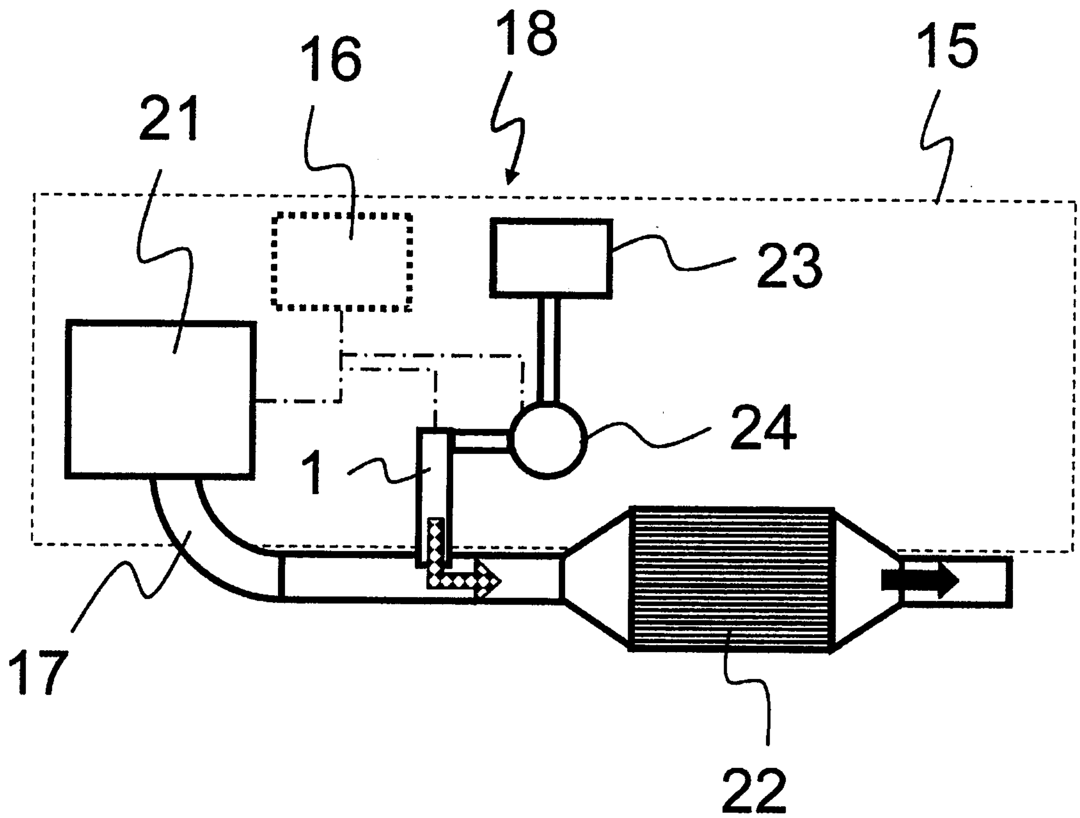

FIG. 2

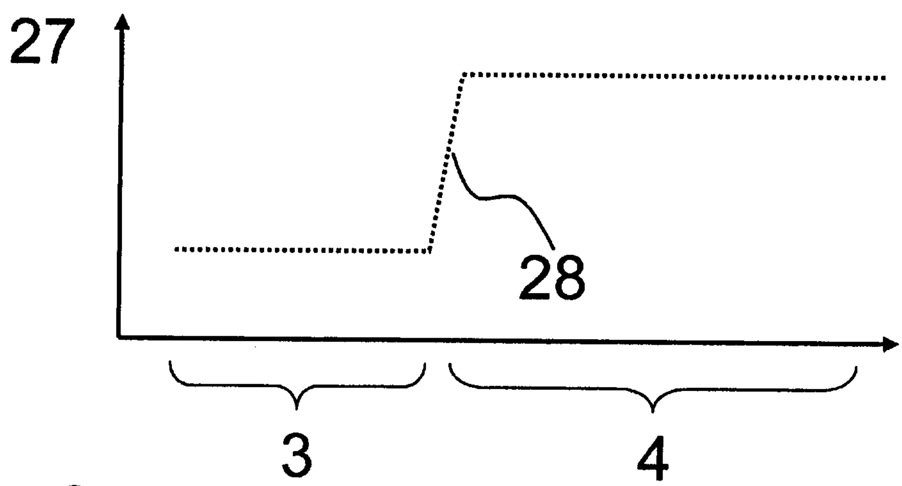

FIG. 3

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The present invention relates to a device for evaporating a urea-water solution, that is to say in particular to an evaporation unit for generating a gas flow. A device of said type is used in particular for the provision of gaseous ammonia for exhaust-gas aftertreatment systems in motor vehicles.

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 said exhaust gas after a hydrolysis carried out outside the exhaust gas. Here, 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 into the exhaust gas upstream of a hydrolysis catalytic converter, is changed into the gaseous state and is brought into contact with the hydrolysis catalytic converter. The ammonia which is generated in this way then reacts for example with a so-called SCR (Selective Catalytic Reduction) catalytic converter further downstream in the exhaust system, with the nitrogen oxides contained therein to form molecular nitrogen and water.

Temperature control is particularly difficult during the evaporation of a urea-water solution. This is the case in particular when firstly the required quantities of the urea-water solution and secondly the available temperatures in the exhaust gas (for example in the case of a mobile application) vary significantly. If only incomplete evaporation is obtained, intermediate products may form, which can possibly lead to the evaporating 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 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 said undesired compounds, which can in part be removed again only with difficulty.

Taking this as a starting point, it is an object of the present invention to at least partially solve the problems highlighted with regard to the prior art. It is sought in particular to specify a device for evaporating a urea-water solution, by means of which device it is achieved that the urea-water solution is evaporated quickly and as completely as possible, wherein in particular the formation of the undesired by-products is considerably reduced. It should be possible to realize this in particular even under the intensely varying demands with regard to different quantities of the urea-water solution to be evaporated. Furthermore, the device should be suitable for realizing, if appropriate in addition to the evaporation, yet further possibilities for the treatment of the reducing agent precursor or the conversion into ammonia.

Said objects are achieved by means of a device according to the features of patent claim 1. Further advantageous embodiments and applications of the invention are specified in the dependent patent claims. It should be noted that the features specified individually in the patent claims may be combined with one another in any desired technologically expedient manner and form further embodiments of the invention. The invention is also characterized further, and rendered more precisely, by the description, in particular in conjunction with the figures.

The device according to the invention for evaporating a urea-water solution has a delivery duct for the urea-water solution, said delivery duct extending through at least a first zone and a second zone for the introduction of heat energy, wherein the zones can be heated separately from one another, and, in the second zone, the delivery duct initially has a meandering profile in a second inlet region, and thereafter has a rectilinear profile.

The device is preferably a separate component which can be operated independently. For this purpose, the device may be formed for example in the manner of a cartridge with a separate housing.

A delivery duct for the urea-water solution is now provided in said device. It is very particularly preferable for precisely one delivery duct to be provided through which the urea-water solution to be evaporated is conducted. For the evaporation of the urea-water solution, it has proven to be advantageous for the urea-water solution to initially be pre-conditioned to a medium temperature, for example in a temperature range above 100°C but below 200°C, before the heat energy required for the evaporation is actually introduced. For this reason, the delivery duct extends through at least two zones in which the heat energy can be introduced into the delivery duct with different intensities and with the capability for mutually separate regulation. Here, the transition from the first zone to the second zone, in which the evaporation ultimately takes place, has proven to be particularly critical. The differences in evaporation quality in said region arise from the fact that, in the case of a mobile application, different delivery rates in each case must be changed into the gaseous state in the evaporator. Here, the delivery rates vary with such intensity that temperature control alone cannot permanently ensure the elimination of the undesired by-products. The delivery rates or evaporation rates of the urea-water solution amount to up to 125 ml/min [millimeters per minute] depending on requirements and engine specification. Here, Leidenfrost effects, excessively intense local cooling and insufficient introduction of heat into the urea-water solution are only some effects which have impeded an evaporation in the case of an abrupt temperature change at the transition from the first zone to the second zone. This applies in particular to delivery rates of down to 15 ml/min and very particularly down to 2 ml/min.

To obtain a considerably improved evaporation result and to reduce the tendency of the delivery duct to become blocked during said steady-state operation, it has been found to be expedient for the delivery duct to initially be of meandering design in the second zone, and of rectilinear design thereafter. A meandering profile means here in particular that, in the inlet region of the second zone, the delivery duct extends not rectilinearly (for example along a longitudinal axis) but rather preferably has a multiplicity of coils, loops, windings or the like. As the urea-water solution flows through said region, intensive contact with the delivery duct wall and thorough mixing of the urea-water solution are attained owing to the forced change in direction, and this leads to a faster and more complete evaporation.

It is also considered to be advantageous for the delivery duct to have a meandering profile in a second outlet region in the second zone. This means for example that the second zone is formed with three regions, specifically an inlet region, a central region and an outlet region, wherein the delivery duct has the following profile forms directly adjoining one another in series: meandering profile, rectilinear profile, meandering profile. It is also preferable for the individual second regions to be of different lengths; in particular, the second central region is designed to be longer than the second inlet region, which in turn is preferably longer than the second outlet region. If appropriate, a separate heating element may be provided for each region, though it is also possible for a plurality of heating elements to extend over one region.

Furthermore, it has been found to be advantageous for a transition region from the first zone to the second zone of the delivery duct to be formed with an enlarged cross section. The duct cross section may for example lie in a range from 0.2 mm^2 to 30 mm^2, wherein the delivery duct is preferably formed in the transition region with a duct cross section of 10 mm^2 to 16 mm^2, in particular of approximately 12 mm^2. Said capability for expansion of the urea-water solution directly upstream of the inlet into the second zone has also proven to be advantageous for the elimination of undesired by-products.

In one refinement of the invention, in the first zone, the delivery duct initially has a rectilinear profile in a first inlet region, and thereafter has a meandering profile. Said first zone preferably has precisely only two regions, wherein the delivery duct merges directly from the rectilinear profile into the meandering profile. It is preferable for the first inlet region and the first outlet region to be of approximately equal length, and for in each case separately operable electric heating elements to be provided.

Furthermore, it is also considered to be advantageous for the first zone and the second zone to be connected by means of a pipe which surrounds the delivery duct. In other words, this also means that the first zone and the second zone are preferably substantially thermally separated from one another, such that the desired temperatures can be set in the first zone and in the second zone in a precise manner. In this way, it is possible in the transition region between the first zone and the second zone to attain a significant temperature step, which likewise promotes the evaporation without undesired by-products. For example, while the delivery duct is thus connected in the first zone and in the second zone to the heating elements via a heat-transmitting layer (for example an aluminum body or copper granulate), the delivery duct is formed in the transition region with a pipe which is for example of heat-insulating design.

The invention is also refined in that the delivery duct is formed with a capillary which is arranged so as to be in heat-conducting contact with at least one electric heating element. The capillary is for example a separate component, in particular in the form of a small pipe. Depending on what type of treatment of the urea-water solution is desired in this device, the capillary may be formed with a corresponding material and/or surface roughness. For example, if the capillary should also perform a hydrolytic function, the surface roughness may lie in the range from 4 to 20 μm [micrometers], wherein the capillary is then preferably formed with titanium. It is however also preferable for the delivery duct to have a low surface roughness, in particular less than 10 μm or even less than 5 μm, in the second inlet region with the meandering profile. As electric heating elements, use is made in particular of self-regulating heating resistors, so-called PTC resistors (PTC: Positive Temperature Coefficient). This is to be understood to mean a positive temperature coefficient which allows the heat conductor to operate in a self-regulating manner about a setpoint temperature. Self-regulating heating resistors of said type are constructed for example from ceramic materials, such as for example barium titanate ceramics and/or doped polymers. Such self-regulating heating resistors permit simple actuation. Here, it is preferable for the electric heating elements to not directly be in contact with the capillary or the delivery duct, but rather for a heat-transmitting layer to be provided, in which the electric heating elements and the capillary are embedded. Said heat-transmitting layer comprises preferably copper and/or aluminum.

For the operation of the device according to the invention described here, it is proposed that the urea-water solution is pre-heated in the first zone to a temperature in the range from 100°C to 180°C, and is evaporated in the second zone at a temperature in the range from 420°C to 490°C. Accordingly, an (only) two-stage heating process is proposed here which is characterized by a temperature step of more than 200°C. The method is in particular suitable for evaporating very small amounts of urea-water solution, for example with a mean throughput of down to 10 ml/min. Precisely these rates will however occur consistently in the mobile application of the device, such that this represents the critical load range. The design according to the invention makes it possible for the first time to reliably avoid blockage of the delivery duct even at these low throughputs.

The invention is used in particular in a motor vehicle having a controller and having an exhaust system with a reducing agent metering system, wherein the reducing agent metering system has at least one device according to the invention, and the controller is set up to carry out the method according to the invention for an intermittent metered addition of reducing agent. Accordingly, the device is used at least for the evaporation of urea-water solution, which (if appropriate, after being brought into contact with a hydrolysis catalytic converter, as ammonia) is added to the exhaust gas in the gaseous state. Consequently, the device serves in particular for the evaporation (and hydrolysis) of the urea-water solution outside the exhaust gas. The ammonia (reducing agent) formed in the device or in the exhaust system permits a conversion, in the exhaust system, of undesired nitrogen oxides in the presence of a so-called SCR catalytic converter. The SCR process is known, and therefore a more detailed explanation will not be given. With regard to the execution of the method, it is also pointed out that an "intermittent" metered addition means in particular that no continuous flow of reducing agent to the exhaust system is obtained, but rather dosed quantities of the reducing agent or of the urea-water solution are added in each case at predefined points in time.

The invention and the technical field will be explained below on the basis of the figures. It is pointed out that the invention is not restricted to the subject matter of the figures. In the figures, in each case schematically:

Fig. 1: shows a preferred design variant of the device according to the invention,

Fig. 2: shows a possible example of the integration of the device into a mobile exhaust system, and

Fig. 3: shows the introduction of temperature into the urea-water solution in a device according to the invention.

Fig. 1 shows a preferred embodiment of the device according to the invention for the evaporation of a urea-water solution. Here, the device 1 is constructed with two zones and five independent heating elements, wherein the first zone 3 and the second zone 4 are of asymmetric design.

The urea-water solution to be evaporated enters into the device 1 for example at the left via the delivery duct 2. Here, the delivery duct 2 is formed with a rectilinear profile 7 in a first inlet region 11, before the delivery duct 2 merges into a meandering profile 6 in the region of the directly adjoining outlet region 19. Within said first zone 3, and also later in the second zone 4, the delivery duct 2 is formed with a capillary 13 which is embedded in a heat-transmitting layer 29 (indicated here by hatching). Also provided in said heat-transmitting layer 29 are the heating elements 14, wherein it is shown here in Figure 1 that both the first inlet region 11 and also the first outlet region 19 each has a separately regulable heating element 14. In the design variant shown here, the first inlet region 11 and the first outlet region 19 are of approximately the same length, wherein the two regions directly adjoin one another, and no further regions are provided in the first zone 3. The same temperature is set by means of the heating elements 14 both in the first inlet region and also in the first outlet region 19, in particular in a very narrow temperature window such as for example 110°C to 120°C.

After exiting the first zone 3, the pre-conditioned urea-water solution flows in the delivery direction 25 through the transition region 9, wherein here the delivery duct 2 is formed by a pipe 12. It can be clearly seen here that said transition region 9 is not formed with the heat-transmitting layer 29, such that here there is a strict temperature division between the first zone 3 and the second zone 4.

Proceeding from said transition region 9, the urea-water solution flows into the second zone 4 in the delivery direction 25. The second zone 4 is in turn formed with the separately operable heating elements 14 which, as is the case in the delivery duct with the capillary 13, are embedded in the heat-transmitting layer 29. According to the invention, the urea-water solution firstly flows through a second inlet region 5, in which the delivery duct 2 has a meandering profile 6. Adjoining said second inlet region there is provided a second central region 20 in which the delivery duct 2 is rectilinear. Following said second central region there is also a second outlet region 8, wherein here the delivery duct 2 is again provided with a meandering profile.

In the design proposed here, it can be seen that the first zone 3 and the second zone 4 are of uneven or asymmetrical construction. It can also be seen that the construction of the second zone 4 itself is of uneven design, that is to say asymmetrical, in particular with regard to the configuration of the second inlet region 5, of the second central region 20 and of the second outlet region 8. Even though the delivery duct 2 is of asymmetrical construction in the second zone 4, it is nevertheless possible for three adjacently arranged, independently operable heating elements 14 to be provided, wherein in particular a plurality of heating elements 14 act on the second central region 20. This is not a problem because substantially the same temperature (for example 440°C – 470°C) is set by means of all three heating elements 14.

Figure 2 schematically shows a motor vehicle 15 having an engine 21. The exhaust gas produced in the engine 21 is discharged via an exhaust system 17 to the atmosphere, wherein the exhaust gases are treated further in the exhaust system 17 in order to minimize the discharge of pollutants to the environment. The exhaust system 17 in figure 2 shows a single catalytic converter 22, in particular an SCR catalytic converter, wherein a reducing agent is supplied to the exhaust gas before it impinges on said catalytic converter 22. Here, the reducing agent is for example vaporous urea, or if hydrolysis has already taken place, vaporous ammonia. To inject said reducing agent, use is made in particular of the described device 1 according to the invention. Here, the motor vehicle 15 is therefore equipped with a reducing agent metering system 18 for the exhaust system 17. The reducing agent metering system 18 comprises for example a tank 23 for the urea-water solution and also a delivery unit 24 which can conduct the reducing agent to the device 1 or to the exhaust system 17, according to demand. For dosing of reducing agent according to demand, a controller 16 is also provided by means of which the operation of the device 1 and/or of the delivery unit 24 is realized. For said operation, it is if appropriate also possible for information regarding the operation of the engine 21 to be processed, as well as other measurement values or calculation results relating to the processes in the exhaust system.

Finally, figure 3 is intended to illustrate that an abrupt temperature change is attained by means of the device. The diagram illustrates the temperature 27 of the urea-water solution as it flows through the first zone 3 and the second zone 4. A particular characteristic of said temperature treatment is that a significant temperature step 28 is realized in the short transition zone between the first zone 3 and the second zone 4. The formation of undesired by-products can be considerably limited in this way.

The invention is used in particular for the evaporation of a urea-water solution (as is also known under the trade name AdBlue) before it is brought into contact with the exhaust gas. Hydrolysis may also take place within the device, such that the urea is converted into ammonia already in the device, such that the ammonia itself is added to the exhaust gas. It is however basically also possible for the urea vapor to be added directly to the exhaust gas, with ammonia being generated there as a result of thermolysis. Hydrolysis within the exhaust gas is also possible, wherein a corresponding catalytic converter may be used.

The invention is aimed in particular at the metered addition of small quantities of the reducing agent or of the urea-water solution. This has been found to result in insufficient evaporation and a high tendency of conventional evaporation units to become blocked during operation. The device is self-evidently also capable of realizing greater throughputs of reducing agent such as arise in mobile application in motor vehicles, wherein these are non-critical. The device presented may furthermore be of very compact construction, for example in the form of a cartridge, such that it can be accommodated in a space-saving manner in the exhaust system, if appropriate also as a retrofit package.

List of reference symbols

1	Device
2	Delivery duct
3	First zone
4	Second zone
5	Second inlet region
6	Meandering profile
7	Rectilinear profile
8	Second outlet region
9	Transition region
10	Cross section
11	First inlet region
12	Pipe
13	Capillary
14	Heating element
15	Motor vehicle
16	Controller
17	Exhaust system
18	Reducing agent metering system
19	First outlet region
20	Second central region
21	Engine
22	Catalytic converter
23	Tank
24	Delivery unit
25	Delivery direction
26	Temperature
27	Time
28	Temperature step
29	Heat-transmitting layer