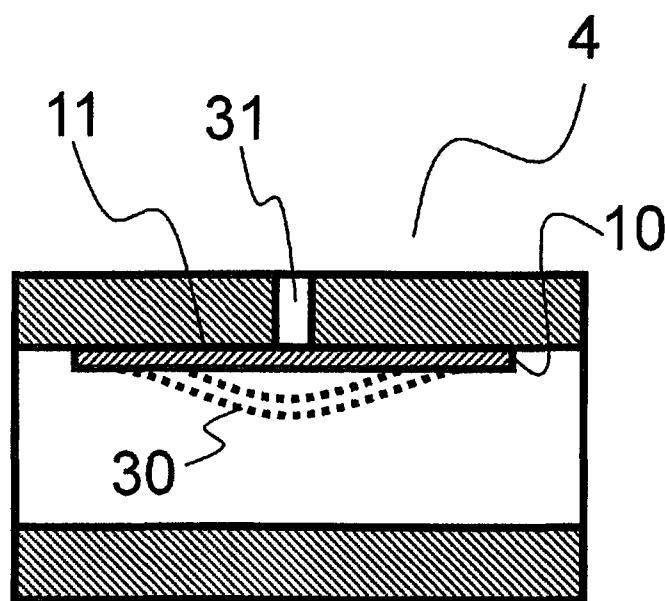


ORIGINAL

DELIVERY DEVICE FOR A REDUCING AGENT HAVING A  
COMPENSATION ELEMENT

Abstract of the Invention

The invention relates to a delivery device (1) for delivering liquid reducing agent having at least one first compensation element (4), wherein the delivery device (1) comprises at least one reducing agent tank (2) for delivering, guiding, and injecting a reducing agent, a delivery unit (6) and a reducing agent line (7), and an injection unit (8), together comprising a total volume (9) that can be filled with reducing agent, wherein the at least one first compensation element (4) is suitable for shrinking the total volume (9) in case of a vacuum in the delivery device (1).



**Fig. 3**

We Claim:

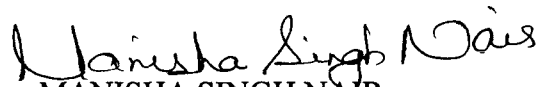
1. A delivery device (1) for delivering liquid reducing agent, having at least one first compensation element (4), wherein for delivering, conducting and metering a reducing agent, the delivery device (1) comprises a reducing agent tank (2), a delivery unit (6) and also a reducing agent line (7) and a metering unit (8), which together have an overall volume (9) that can be filled with reducing agent, wherein the at least one first compensation element (4) is suitable for reducing the size of the overall volume (9) when a negative pressure prevails in the delivery device (1).
2. The delivery device (1) as claimed in claim 1, wherein the at least one first compensation element (4) is designed in the form of a diaphragm (10), for which there is provided a contact surface (11) designed such that, when a positive pressure prevails in the delivery device (1), the diaphragm (10) bears substantially immovably against said contact surface (11) and, when a negative pressure prevails in the delivery device (1), the diaphragm (10) can move into the overall volume (9).
3. The delivery device (1) as claimed in one of the preceding claims, wherein the at least one first compensation element (4) permits a reduction in size of the overall volume (9) by up to 5%.
4. The delivery device (1) as claimed in one of the preceding claims, wherein the at least one first compensation element (4) permits a reduction in size of the overall volume (9) by up to 5% at a negative pressure of lower than 500 mbar.
5. The delivery device (1) as claimed in one of the preceding claims, wherein there is at least one second compensation element (25) which is suitable for increasing the size of the overall volume (9) when a threshold positive pressure (12) is reached in the delivery device, wherein when a pressure below the threshold positive pressure (12) prevails, the at least one second

compensation element (25) permits substantially no increase in size of the overall volume (9).

6. The delivery device (1) as claimed in claim 5, wherein the threshold positive pressure (12) is at least 5 bar.
7. The delivery device (1) as claimed in claim 5 or 6, wherein the at least one second compensation element (25) can increase the size of the overall volume (9) by up to 15%.
8. The delivery device (1) as claimed in one of claims 5 to 7, wherein the at least one second compensation element (25) increases the size of the overall volume (9) substantially abruptly when the threshold positive pressure (12) is reached.
9. The delivery device (1) as claimed in one of claims 5 to 8, wherein the at least one second compensation element (25) is designed in the form of a surface part (13) under preload, wherein when a positive pressure above a threshold positive pressure (12) prevails, the surface part (13) can move counter to the preload, such that the overall volume (9) increases in size.
10. The delivery device (1) as claimed in one of claims 5 to 9, wherein the at least one first compensation element (4) and at least one second compensation element (25) are formed jointly as a combined compensation element.
11. The delivery device (1) as claimed in one of the preceding claims, wherein the at least one first compensation element (4) is arranged between the delivery unit (6) and metering unit (8).

12. A method for the freezing of liquid reducing agent in a delivery device (1) which has an overall volume (9) filled with liquid reducing agent, having at least the following steps:
- a) cooling of the reducing agent in the delivery device (1), wherein the overall volume (9) of the delivery device (1) is decreased in size by means of a first compensation element (4); and
  - b) freezing of the reducing agent in the delivery device (1), wherein the overall volume (9) of the delivery device (1) is increased in size by means of a second compensation element (4).
13. A motor vehicle (14) comprising an internal combustion engine (15) and an exhaust system (3) designed for carrying out a selective catalytic reduction and a delivery device (1) for delivering reducing agent out of a reducing agent tank (2) into the exhaust system (3), as claimed in one of claims 1 to 11.

Dated this the 1<sup>st</sup> Day of March, 2012

  
MANISHA SINGH NAIR  
Agent for the Applicant [IN/AP-740]  
LEX ORBIS IP PRACTICE

ORIGINAL

18 56 DE 1.2  
01 MAR 2012

1/3

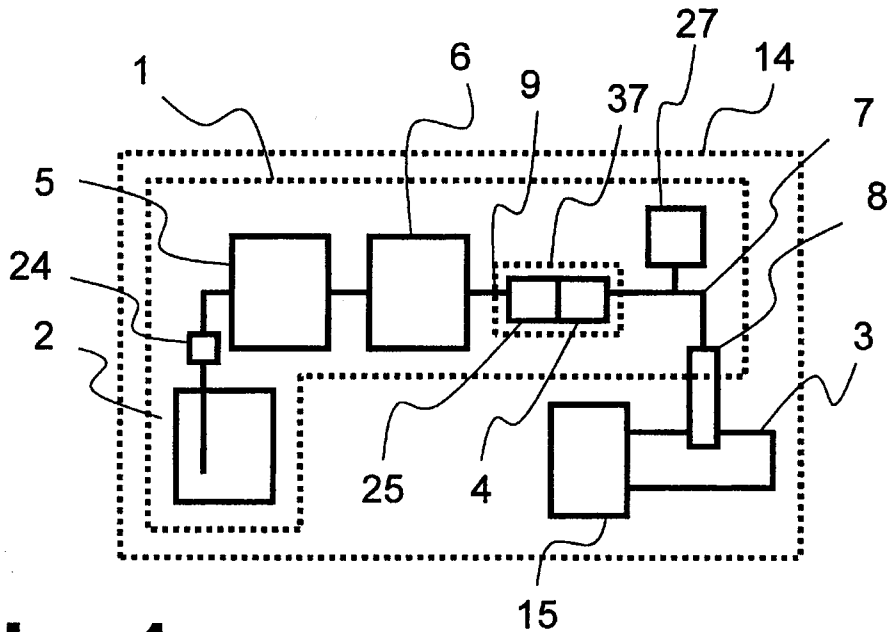


Fig. 1

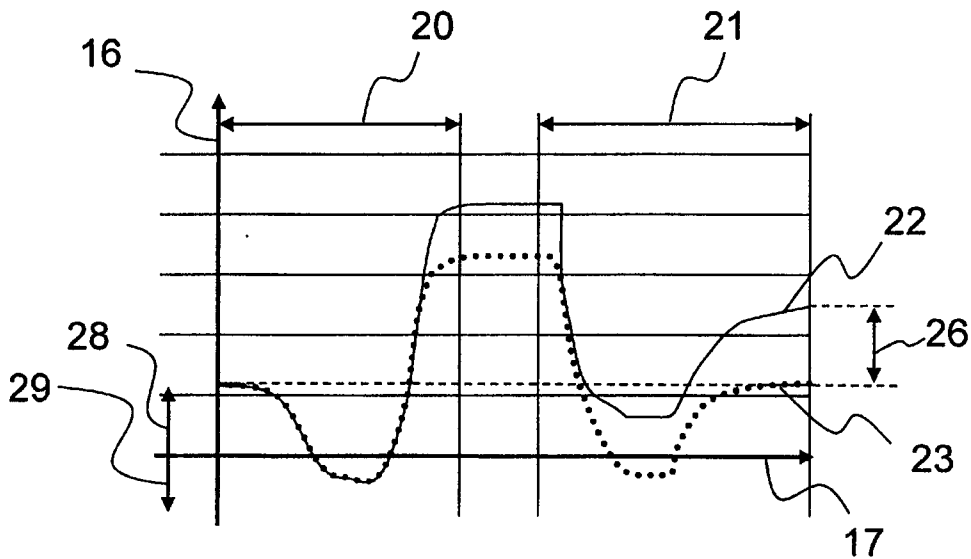


Fig. 2

*Manisha Singh Nair*  
MANISHA SINGH NAIR  
Agent for the Applicant [IN/PA-740]  
LEX ORBIS IP PRACTICE

ORIGINAL

18 56 DE/12

01 MAR 2012

2/3

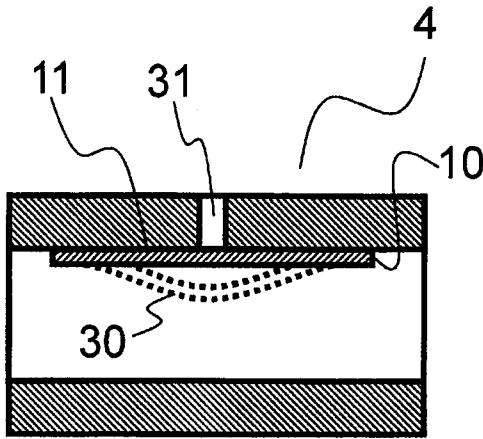


Fig. 3

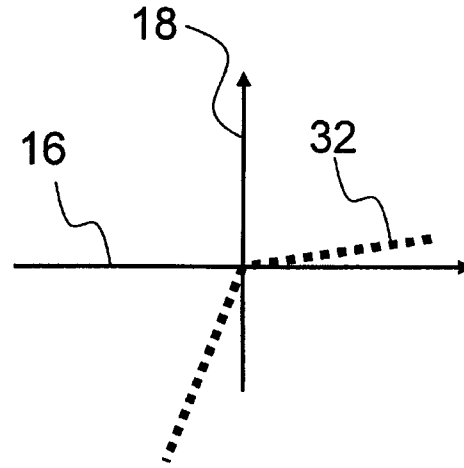


Fig. 4

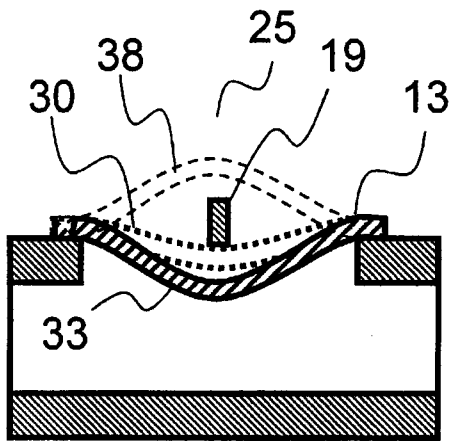


Fig. 5

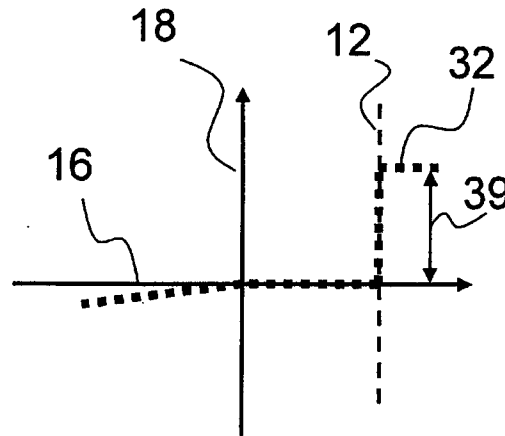


Fig. 6

*Manisha Singh Nair*  
MANISHA SINGH NAIR  
Agent for the Applicant [IN/PA-740]  
LEX ORBIS IP PRACTICE



The present invention relates to a delivery device for delivering liquid reducing agent out of a reducing agent tank into an exhaust-gas purification system, wherein the delivery device comprises a special compensation element.

With regard to present emissions limit values, which will be further tightened in the near future, for exhaust gases of internal combustion engines, increasing use is being made, in utility vehicles and motor vehicles, of SCR systems for exhaust-gas purification. Here, reducing agent is used in a variety of forms, in particular in the form of reducing agent precursors which are present in aqueous solution (Denoxium, AdBlue). AdBlue is the trade name of an available urea-water solution with a urea fraction of approximately 32.5 percent by weight. In the use of SCR technology it must be noted that freezing of the reducing agent is possible at low ambient temperatures or else through cooling effects as a result of convection. An aqueous urea-water solution typically freezes at temperatures below  $-11^{\circ}\text{C}$ . As a result of the increase in volume owing to the phase change of the reducing agent from liquid to solid, components of the SCR system, for example filters, reducing agent lines or valves of the delivery device, can be damaged.

As a solution to said known problem, it has been proposed that, for compensating the expansion, flexible reducing agent lines or reducing agent lines with volume compensation elements be provided, which increase the volume of reducing agent lines as a result of the ice pressure of the frozen reducing agent or reducing agent precursor. It has however not yet been possible for this to be developed into a cheap and reliable form of protection appropriate from a component aspect.

It is an object of the present invention to specify a delivery device for reducing agent, having a compensation element, which is further improved in relation to the prior art, wherein the compensation element further reduces the risks posed

to the delivery device by the freezing process. Furthermore, it is sought to propose a targeted freezing method for a delivery device of said type.

Said objects are achieved by means of a delivery device according to the features of claim 1 and also by means of a method according to the features of claim 12. Further advantageous refinements of the device are specified in the dependent claims. The features specified individually in the claims may be combined with one another in any desired technologically meaningful way and may be supplemented by explanatory facts from the description, with further design variants of the invention being specified.

The device according to the invention is a device for delivering liquid reducing agent, having at least one first compensation element, wherein for delivering, conducting and metering a reducing agent, the delivery device comprises a reducing agent tank, a delivery unit and also a reducing agent line and a metering unit, which together have an overall volume that can be filled with reducing agent, wherein the at least one first compensation element is suitable for reducing the size of the overall volume when a negative pressure prevails in the delivery device.

Within the context of the present invention, a negative pressure means a negative pressure in relation to the ambient pressure. Likewise, a positive pressure means a positive pressure in relation to the ambient pressure.

The present invention is based on the realization that, before the freezing of a reducing agent in a delivery device, cooling of the reducing agent always takes place, and during said cooling, a reduction in volume of the reducing agent takes place. Measurements with an aqueous urea solution have shown that a significant reduction in volume takes place already during the cooling of the reducing agent from 20°C to 0 °C. In delivery devices known from the prior art, owing to said reduction in volume, a vacuum is formed in the delivery device, which vacuum causes additional reducing agent to be delivered from the reducing agent tank into

the delivery device through the valves of the delivery unit. As a result, the filling level of the delivery device increases during cooling. When reducing agent which has cooled to this extent cools further, it begins to freeze at temperatures of approximately -11 °C. Here, an increase in volume now takes place which is greater than the reduction in volume that takes place previously during cooling. Said increase in volume leads to an increased pressure in the delivery device. Said increase in pressure is greater the more additional reducing agent has been additionally sucked into the delivery device through the delivery unit during the reduction in volume during cooling. By means of the compensation element according to the invention, the amount of additional reducing agent in the delivery device can be reduced or even completely eliminated, such that in a delivery device according to the invention, lesser measures need be taken to ensure that the delivery device withstands the ice pressure.

It is particularly advantageous here if the delivery device does not decrease in volume for as long as no negative pressure prevails in the delivery device, and the first compensation element very quickly and very freely permits a reduction in volume when a negative pressure prevails. In this way, it can be ensured that the delivery device exhibits substantially incompressible behavior in the operating range, that is to say at pressures above 0 bar. In this way, it is possible to attain a high degree of uniformity of the reducing agent pressure provided by the delivery device. At the same time, no unnecessary energy is expended for an elastic expansion of the delivery device as a result of a pressure increase during operation.

The delivery device is furthermore particularly advantageous if the at least one first compensation element is designed in the form of a diaphragm, for which there is provided a contact surface designed such that, when a positive pressure prevails in the delivery device, the diaphragm bears substantially immovably against said contact surface and, when a negative pressure prevails in the delivery device, the diaphragm can move into the overall volume.

The contact surface may for example be a portion of an inner wall of a line of the delivery device.

In the contact surface downstream of the diaphragm there may be provided, for example, a bore through which air or the like can pass freely between the diaphragm and the contact surface when a negative pressure prevails in the delivery device. The air which is separated from the overall volume of the delivery device by the diaphragm thus fills a part of the overall volume in the delivery device. The diaphragm can preferably be very easily deformed when a negative pressure prevails, because the large surface area of the relatively thin diaphragm can bend easily. When a positive pressure prevails, the diaphragm is pressed against the contact surface. A movement of the diaphragm is then possible for example only in the region of the described bore in the contact surface. Said bore is however very small in relation to the contact surface against which the diaphragm bears. As viewed over the very small area of the bore, the diaphragm is relatively rigid, even though it has the same thickness there as it does in the other regions. For this reason, the diaphragm cannot expand to a significant extent into the bore, such that there is no significant increase in the overall volume when positive pressures prevail in the system.

As an alternative to a bore, a grate may also be provided downstream of the diaphragm. It is then again possible for the diaphragm to freely expand into the overall volume, whereas when a positive pressure prevails in the system, the diaphragm bears against the grate and an expansion of the diaphragm into the individual openings of the grate does not take place to a significant extent.

It would also be possible for the diaphragm to be formed, in parts, with different thicknesses. That region of the diaphragm which comes to rest over the bore or the grate could be designed to be thicker in order that the abutting diaphragm does not deform. Adjacent regions could be designed to be thin and flexible, optionally even with a corrugation, in order that free mobility of the diaphragm is ensured here when the latter moves into the overall volume of the delivery device when a

negative pressure prevails. The movable regions of the diaphragm could possibly also be formed with a corrugation or the like in order to ensure yet further increased flexibility here.

It is also possible for a diaphragm to be provided which is composed of different materials. Either a relatively rigid material with a relatively high modulus of elasticity and/or with a relatively large thickness can be used in individual regions of the diaphragm, and/or the diaphragm may be stiffened in regions by means of an additional layer and/or a stiffening structure.

The delivery device according to the invention is particularly advantageous if the at least one first compensation element permits a reduction in size of the overall volume by up to at most 5%.

It has been found in experiments that reductions in volume by up to 5% can occur during the freezing of aqueous reducing agent proceeding from conventional operating temperatures, which may typically be 20°C or even up to 80°C. It is however preferable for the first compensation element to permit reductions in volume by at least 2% of the overall volume.

The delivery device according to the invention is furthermore particularly advantageous if the at least one first compensation element permits a reduction in size of the overall volume by up to 5% at a negative pressure of lower than 500 mbar [millibar]. Here, it is particularly preferable for a reduction in volume by up to 2% to be possible at a negative pressure of lower than 500 mbar [millibar], preferably lower than 200 mbar [millibar] and particularly preferably lower than 100 mbar [millibar].

This embodiment of the delivery device according to the invention is based on the notion that the negative pressure in the delivery device should not become very large, such that no additional reducing agent is sucked out of the reducing agent tank into the delivery device. When low negative pressures prevail in the system,

there is a lower probability of this occurring, and/or no measures or lesser measures need be taken to prevent reducing agent from being sucked in from the reducing agent tank. Also, a flow resistance may be provided in a suction line for sucking reducing agent out of a reducing agent tank, which flow resistance ensures that reducing agent does not flow from the reducing agent tank into the delivery device when cooling of the delivery device is taking place. Such a flow resistance is intended merely to ensure that the negative pressure required for volume reduction by means of the first compensation element is lower than the negative pressure at which additional reducing agent is sucked in from the reducing agent tank.

The delivery device according to the invention is also particularly advantageous if there is at least one second compensation element which is suitable for increasing the size of the overall volume when a threshold positive pressure is reached in the delivery device, wherein when a pressure below the threshold positive pressure prevails, the at least one second compensation element permits substantially no increase in size of the overall volume.

Such a second compensation element (expansion element) thus increases the size of the volume of the delivery device when a certain threshold positive pressure is exceeded. It is preferable for no significant increase in size of the overall volume to take place before this. The reason for this is that, in the range of the delivery pressures at which the delivery device according to the invention is operated, the delivery device should exhibit the most rigid behavior possible in order to permit particularly energy-efficient and reliable delivery of reducing agent. When the reducing agent in the delivery device has cooled completely and an expansion of the reducing agent occurs on account of the freezing process, pressures arise which are significantly higher than the normal delivery pressures. The second compensation element now permits a controlled increase in size of the overall volume at such pressures, such that the ice pressure in the delivery device does not cause damage.

The delivery device according to the invention is particularly advantageous if the threshold positive pressure is at least 5 bar. The threshold positive pressure is specified here in each case as a pressure above the ambient pressure, that is to say relative to the ambient pressure. Delivery pressures of the delivery devices are normally less than 5 bar. It is however also possible to use higher delivery pressures, for example up to at most 10 bar or even up to at most 15 bar. It would for example be expedient for the threshold pressure to be set so as to be at least 1 bar higher than the maximum delivery pressure of the delivery device.

The delivery device according to the invention is particularly advantageous if the at least one second compensation element can increase the size of the overall volume by up to 15%. It is preferable if the second compensation element can increase the size of the overall volume by at most between 2 and 15%, in particular at most between 3 and 10%. It has been found in experiments that such increases in the size of the volume can regularly occur during the freezing of reducing agent. It is preferable to provide precisely only one second compensation element which permits this.

The delivery device according to the invention is furthermore particularly advantageous if the at least one second compensation element increases the size of the overall volume substantially abruptly when the threshold positive pressure is reached. As a result of such an abrupt (sudden, immediate) increase in size, the ice pressures arising in the delivery device during the freezing process do not become greater than the threshold positive pressure. It is also possible for the second compensation element to be constructed such that, when the positive pressure is reached, an abrupt reduction in pressure in the delivery device takes place at the same time as the abrupt increase in size of the overall volume. With a second compensation element of said type, when the threshold positive pressure is reached, a stable equilibrium position is assumed, such that the overall volume is not reduced in size again despite the sudden pressure drop.

In addition or alternatively, above the threshold positive pressure, a continuous increase in size of the overall volume can take place with a further increase in

pressure. With such a design, however, the pressure in the delivery device would rise still further above the threshold positive pressure.

The delivery device according to the invention is also particularly advantageous if the at least one second compensation element is designed in the form of a surface part under preload, wherein when a positive pressure above a threshold positive pressure prevails, the surface part can move counter to the preload, such that the overall volume increases in size. A surface part under preload typically behaves in the manner of a clicker. If said surface part is loaded counter to the preload by a certain force, or by a certain pressure acting on the surface part, said surface part abruptly snaps over, resulting in a sudden increase in the size of the volume. It is generally expedient if, during a sudden snap-over, the surface part moves against a stop and bears against the latter without reaching a further stable position. From a further stable position, the surface part would only be able to pass back into the original preloaded position under the action of a corresponding counterpressure or a corresponding counteracting force. By means of a stop, the surface part can be prevented from reaching a further stable position, such that the surface part snaps back into the preloaded position when the pressure falls below the threshold positive pressure.

The delivery device according to the invention is also particularly advantageous if the at least one first compensation element and at least one second compensation element are formed jointly as a combined compensation element. It is for example possible for a large surface part which is under preload to be provided as a second compensation element, and for a first compensation element in the form of a diaphragm to be provided directly on said surface part. The surface part under preload then has, for example, a corresponding bore in order that air can pass between the diaphragm and the surface part. It is also possible for the first compensation element and the second compensation element as a combined compensation element to be formed singly and in a compact integrated component.

The delivery device according to the invention is furthermore advantageous if the at least one first compensation element is arranged between the delivery unit and the metering unit. The high-pressure region of a delivery device is generally situated between the delivery unit and the metering unit because the pressure is generated in the delivery device by the delivery unit and is dissipated by the metering unit, which supplies the reducing agent into the exhaust system of an internal combustion engine. The metering unit is for example an injector. The delivery unit is for example a pump. There is generally situated in said high-pressure region pressurized reducing agent which cannot expand into a large volume, for example the tank. It is particularly preferable for the first compensation element to be arranged close (in particular directly adjacent) to the delivery unit. The freezing process can then take place proceeding from the metering unit in the direction of the first compensation element, such that an ice plug, which would separate a still-liquid volume of reducing agent from the first compensation element and thereby prevent the first compensation element from imparting its compensating effect, is not formed in the delivery device. Here, it is also considered to be particularly advantageous if the second compensation element, if provided, is likewise provided so as to be arranged between the delivery unit and the metering unit, if possible close to the delivery unit.

The invention also relates to a method for the freezing of liquid reducing agent in a delivery device which has an overall volume filled with liquid reducing agent, having at least the following steps:

- a) cooling of the reducing agent in the delivery device, wherein the overall volume of the delivery device is decreased in size by means of a first compensation element, and
- b) freezing of the reducing agent in the delivery device, wherein the overall volume of the delivery device is increased in size by means of a second compensation element.

In particular, the overall volume of the delivery device is reduced in size in step a) such that there is no follow-up flow of reducing agent into the delivery device.

Furthermore, the increase in volume during the freezing of the reducing agent in step a) is generally greater than the reduction in volume during the cooling in step b).

Such a method may particularly preferably be carried out using a delivery device according to the invention. A particular advantage of the method according to the invention is that the changes in volume of the delivery device always take place in a defined manner at corresponding compensation elements, such that no inadmissible expansions and stresses can arise in the delivery device.

The invention also relates to a motor vehicle comprising an internal combustion engine and an exhaust system which is designed for carrying out a selective catalytic reduction, and a delivery device according to the invention for delivering reducing agent from a reducing agent tank into the exhaust system.

The technical refinements and advantages specified for the delivery device according to the invention are analogously applicable and transferable to the method according to the invention and to the motor vehicle according to the invention. The same applies to the advantages and special technical refinements specified in conjunction with the motor vehicle according to the invention and the method according to the invention, which advantages and refinements can be applied and transferred to the device according to the invention.

The invention and the technical field will be explained in more detail below on the basis of the figures. The figures show particularly preferred exemplary embodiments, to which the invention is however not restricted. In particular, note that the figures and in particular the illustrated proportions are merely schematic. In the figures:

Figure 1: shows a motor vehicle having a first design variant of the delivery device according to the invention;

Figure 2: shows a diagram illustrating the freezing behavior of the delivery device;

Figure 3: shows a design variant of the first compensation element;

Figure 4: shows a pressure/volume characteristic curve of a design variant of the first compensation element;

Figure 5: shows a design variant of the second compensation element;

Figure 6: shows a pressure/volume characteristic curve of a design variant of the second compensation element;

Figure 7: shows a design variant of the combined compensation element;

Figure 8: shows a pressure/volume characteristic curve of a design variant of the combined compensation element;

Figure 9: shows a further refinement of a first compensation element; and

Figure 10: shows a further refinement of a first compensation element.

Figure 1 shows a motor vehicle 14 having an internal combustion engine 15 with an exhaust system 3. The exhaust system 3 has a metering unit 8 for metering a reducing agent (aqueous urea solution) into the exhaust system 3. The reducing agent is supplied to the metering unit 3 from a reducing agent tank 2 by means of a delivery device 1. From the delivery device 2, the reducing agent passes through the reducing agent line 7 to the metering unit 8. Along the reducing agent line 7 from the reducing agent tank 2 to the metering unit 8 there are provided a flow resistance 24, a filter 5, a delivery unit 6, a compensation element 4 and a pressure sensor 27. The sequence of components may deviate in part from the sequence

described here. It is optionally additionally possible for a second compensation element 25 or a combined compensation element 37 to be provided in the region of the first compensation element 4. All the components of the delivery device 1 with the exception of the reducing agent tank 2 together have an overall volume 9. It is also possible for the overall volume 9 to relate only to those components of the delivery device 1 which are arranged between the metering unit 8 and the delivery unit 6. The first compensation element 4 is suitable for reducing the volume 9 of the delivery device 1 when a negative pressure prevails in the delivery device 1. The first compensation element 4 interacts with the flow resistance 24 such that, when a negative pressure prevails, the overall volume 9 of the delivery device 1 can be reduced by means of the first compensation element 4 more easily than additional reducing agent from the reducing agent tank 2 can be sucked into the delivery device 1 through the flow resistance 24.

Figure 2 shows, in a diagram, a simplified illustration of how the pressure in a reducing agent delivery device according to the invention behaves in relation to the pressure in a reducing agent delivery device known from the prior art, during the freezing and thawing processes of the reducing agent contained therein. Plotted on the pressure axis 16 in each case is the reducing agent pressure present in the system. Said pressure is plotted against the time axis 17. The area above the time axis 17 represents positive pressure 28, and the area below the time axis 17 represents negative pressure 29. The first curve 22 depicts the pressure in a delivery device known from the prior art. The second curve 23 depicts the pressure in a delivery device according to the invention. Illustrated firstly is a freezing time period 20. During the cooling of the reducing agent, a negative pressure 29 arises owing to a reduction in volume of the reducing agent. In the delivery device known from the prior art as per the first curve 22, in this case additional reducing agent is sucked into the delivery device from the reducing agent tank. In the delivery device according to the invention as per the second curve 23, said decrease in volume is compensated by a first compensation element, such that no additional reducing agent passes into the delivery device. During the freezing process, the pressure both in the delivery device known from

the prior art and also in the delivery device according to the invention rises considerably. The pressure in the delivery device known from the prior art however rises more intensely because, in said delivery device, additional reducing agent is present which has previously been sucked in by the negative pressure during the freezing process. In a thawing time period 21, the pressure initially falls intensely in both delivery devices. In the delivery device known from the prior art, however, a negative pressure 29 is not attained again, or is attained to a lesser degree than in the delivery device according to the invention, because in the delivery device known from the prior art additional volume has been sucked into the delivery device, which additional volume cannot now escape because the valves in the delivery unit permit only a passage of reducing agent out of the reducing agent tank into the delivery device, and not in the other direction. The reason for this is that the pump is generally a pump with passively acting valves, in which the delivery direction is predefined by the construction of the valves. Therefore, in the case of the freezing and subsequent re-thawing of the reducing agent in a delivery device known from the prior art, the pressure after the re-thawing exhibits a pressure increase 26 in relation to the pressure present before the freezing process, or in relation to the pressure in a delivery device according to the invention.

In interpreting figure 2, it must be noted that figure 2 is merely a simplified illustration of the differences between delivery devices known from the prior art and the delivery device according to the invention. In the diagram in figure 2, only the influence of the first compensation element on the reducing agent volume sucked into the device during cooling, and the influence of said volume on the pressure in the delivery device, have been taken into consideration. In reality, the first compensation element also has a direct influence on the pressure in the delivery device itself. For example, during cooling, the pressure cannot fall as far as in delivery devices known from the prior art, because said pressure drop is already prevented by the first compensation element.

Figure 3 shows a first compensation element 4 according to the invention which is constructed with a diaphragm 10. When a positive pressure prevails, the diaphragm 10 bears against a contact surface 11. When a negative pressure prevails, the diaphragm 10 is deflected into a deflected position 30, wherein air is then present between the diaphragm 10 and the contact surface 11, and said air is sucked through a bore 31 and can escape again at a later time.

Figure 4 shows a pressure/volume curve 32 of a first compensation element as per figure 3. The diagram shows a pressure axis 16 and a volume axis 18. When positive pressures prevail, the volume increases only slightly as per the pressure/volume curve 32. The reason for this is that the diaphragm bears against a contact surface and can deform only very slightly. When negative pressures prevail, there is an intense reduction in volume as per the pressure/volume curve 32. The reason for this is that the diaphragm can move very freely into a deflected position.

Figure 5 shows a second compensation element 25. In a second compensation element 25, there is a surface part 13 which is under preload and which, in normal operation, is held in a preloaded position 33 owing to its preload. If the pressure in the delivery device is now increased, the preloaded surface part 13 snaps over, above a certain pressure, into the deflected position 30. It is preferable if, even in the deflected position 30, the surface part cannot flip over completely but rather bears against a stop 19. It is thus ensured that the surface part 13 does not move into a stable equilibrium position 38 which differs from the preloaded position 33 and from which the surface part 13 could move back only with the exertion of a corresponding counteracting force.

Figure 6 shows a pressure/volume curve 32 of a second compensation element. The volume is plotted on the volume axis 18 against the pressure plotted on the pressure axis 16. When negative pressures prevail, the volume decreases in size only slightly, because the relatively rigid surface part expands only slightly under the acting forces. When positive pressures prevail, the surface part pauses in its

preloaded position, such that substantially no volume expansion takes place. When pressures higher than a threshold positive pressure 12 prevail, the diaphragm flips over suddenly into the deflected position, such that an abrupt increase in volume 39 occurs. When pressures higher than the threshold positive pressure 12 prevail, no significant further increase in volume takes place because the surface part bears against the stop and can deform no further.

Figure 7 shows a combined compensation element 37 composed of a first compensation element 4 having a diaphragm 10, a contact surface 11 and a bore 31, wherein the diaphragm 10 can flip over into a deflected position 30. The second compensation element 25 in figure 7 is likewise composed of a surface part 13 and a stop 19, wherein the surface part 13 is in a preloaded position 33 and can be flipped over into a deflected position 30.

Figure 8 shows a pressure/volume curve 32 of a combined compensation element as per figure 7. The volume is plotted on the volume axis 18 against the pressure on the pressure axis 16. The pressure/volume curve 32 in figure 8 arises substantially from a superposition of the pressure/volume curves from figures 4 and 6. The pressure/volume curve 32 exhibits an intense decrease in volume when negative pressures prevail, and a substantially constant volume when pressures prevail which lie between a neutral pressure and a threshold positive pressure. At the threshold positive pressure 12, an abrupt increase in volume 39 takes place. In said region, the operating range of the delivery device according to the invention is also such that the delivery device according to the invention with a combined compensation element exhibits substantially rigid behavior in the operating range. At a threshold positive pressure 12, a sudden increase in volume occurs. A pressure/volume curve as per figure 8 is always attained if a first compensation element and a second compensation element are provided in a delivery device according to the invention. For this purpose, it is not necessary for the two to be formed as a combined compensation element.

Figure 9 shows an alternative design of a first compensation element 4. Here, too, when a positive pressure prevails in the delivery device according to the invention, a diaphragm 10 bears against a contact surface 11. Instead of a bore 31, there is provided in this case a grate 35 which may be formed for example from a multiplicity of bores 31. Furthermore, the diaphragm 10 is provided with a stiffening structure 34, such that when a negative pressure prevails in the delivery device, the diaphragm 10 can move into a deflected position 30, but a deformation of the diaphragm 10 in the direction of the grate 35 is additionally impeded.

In the embodiment of the first compensation element 4 as per figure 10, there is likewise a diaphragm 10 with a contact surface 11 and a bore 31 in the contact surface 11, wherein the diaphragm 10 can move into a deflected position 36. To enhance the mobility of the diaphragm 10, there is in this case provided on the diaphragm 10 a corrugation 36, as a result of which, when a negative pressure prevails in the delivery device according to the invention, the diaphragm 10 can move more freely into the delivery device according to the invention, or into the overall volume, and into a deflected position 30.

## List of reference symbols

- 1 Delivery device
- 2 Reducing agent tank
- 3 Exhaust system
- 4 First compensation element
- 5 Filter
- 6 Delivery unit
- 7 Reducing agent line
- 8 Metering unit
- 9 Overall volume
- 10 Diaphragm
- 11 Contact surface
- 12 Threshold positive pressure
- 13 Surface part
- 14 Motor vehicle
- 15 Internal combustion engine
- 16 Pressure axis
- 17 Time axis
- 18 Volume axis
- 19 Stop
- 20 Freezing time period
- 21 Thawing time period
- 22 First curve
- 23 Second curve
- 24 Flow resistance
- 25 Second compensation element
- 26 Pressure increase
- 27 Pressure sensor
- 28 Positive pressure

- 29 Negative pressure
- 30 Deflected position
- 31 Bore
- 32 Pressure/volume curve
- 33 Preloaded position
- 34 Stiffening structure
- 35 Grate
- 36 Corrugation
- 37 Combined compensation element
- 38 Stable equilibrium position
- 39 Abrupt volume increase