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(54) **METHOD AND APPARATUS FOR MIXING FLUIDS IN LOW CONCENTRATIONS**

(57) The invention relates to a method of mixing at least a first fluid (1) and a second fluid (2) with one another, the method comprising providing the first fluid (1) in a desired first amount to a mixing vessel (130) having a first volume, providing the second fluid (2) in a desired second amount to the mixing vessel (130), affording a mixed fluid (3) and flowing the mixed fluid (3) through a homogenizer (140) comprising a buffer vessel (142) with a second volume and a filling (144) within the buffer vessel (142), thereby thoroughly mixing the first (1) and second (2) fluids with one another to afford a homogenized mixed fluid (4). The invention further provides an apparatus (100) for performing such a method and a homogenizer (140) for such an apparatus (100).

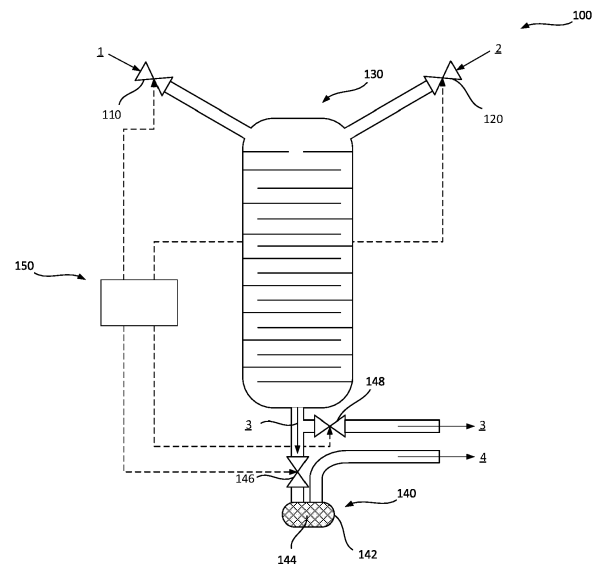


Fig. 1

Description

Background of the invention

[0001] Mixing fluids, particularly gases, in which at least one component has a very low concentration is particularly challenging in terms of homogeneity of the mixed gas. Typically, when at least one component of the mixed fluid is in the ppm range of concentrations, fluctuations in concentration over different partial volumes and over time occur. This problem is particularly relevant in applications, which require a continuous flow or large fluid volumes, because the time required for equilibration by diffusion is very high.

[0002] Diffusion is a process driven by local concentration differences such that the fluid components exhibit a net movement towards places with a smaller concentration. However, single molecules do not move according to a directed flow path towards the location with the lowest concentration. Single molecule movement is rather random Brownian motion, which is mainly influenced by temperature and only on occasions when two molecules come in closer proximity to one another they can attract or repel one another. This is the reason for the long equilibration duration for mixtures with low concentrations. The likelihood for two molecules of the substance with the low concentration to come into contact with one another is very small.

Disclosure of the invention

[0003] The invention provides a method and an apparatus for mixing fluids as well as a homogenizer for such an apparatus with the features set out in the respective independent claims. Advantageous embodiments of those are subject-matter of the respective dependent claims as well as the following description.

[0004] A method of mixing at least a first fluid and a second fluid with one another according to the invention comprises providing the first fluid in a desired first amount to a mixing vessel having a first volume, providing the second fluid in a desired second amount to the mixing vessel, affording a mixed fluid, and flowing the mixed fluid through a homogenizer comprising a buffer vessel with a second volume and a filling within the buffer vessel, thereby thoroughly mixing the first and second fluids with one another to afford a homogenized mixed fluid. Particularly, the filling of the buffer vessel is configured to cause disturbances within the mixed gas flowing through the buffer vessel. Therefore, the mixed fluid is forced to change its flow direction within the homogenizer. The motion of the single molecules is, therefore, not solely governed by Brownian motion, which greatly aids the homogenization of the mixed fluid.

[0005] It is to be understood, that the mixing vessel can be any (particularly but not necessarily closed) hollow structure, in which fluids may be stored, injected, conducted or otherwise kept, like a container or recep-

tacle or a duct or pipe or conduit, and can especially be realized in the form of a duct, into which the at least two fluids are dosed. In some embodiments, a dedicated vessel may be foreseen as the mixing vessel. The mixing vessel, in whatever form provided, may comprise baffle plates in order to provide for disturbances in the flow of the mixed fluid to aid homogenization.

[0006] Be it further noted, that, although the invention is described in the context of mixing two fluids with one another, it may just as well be used for mixing more than two different fluids with one another.

[0007] Particularly, the first fluid and the second fluid are gases.

[0008] Particularly, the second amount is in the range of less than 1%, 0.3%, 0.1%, 300 ppm, 100 ppm, 30 ppm, 10 ppm, 3 ppm, 1 ppm, 300 ppb or less than 100 ppb, in relation to the total amount of the mixed fluid by volume or mass, respectively. This is a concentration regime, which poses particularly difficult challenges in terms of homogenization.

[0009] The method may advantageously further comprise heating the mixed gas flowed through the buffer vessel in order to increase a rate of diffusion within the mixed gas, thereby accelerating the homogenization process.

[0010] An apparatus for mixing at least a first fluid and a second fluid with one another according to the invention comprises a mixing vessel, configured to receive at least the first and the second fluid and to produce a mixed fluid therefrom, a first fluid metering device, configured to provide a desired first amount of the first fluid to the mixing vessel, a second fluid metering device, configured to provide a desired second amount of the second fluid to the mixing vessel, and a homogenizer downstream of the mixing vessel, the homogenizer comprising a buffer vessel with a filling, wherein the filling is configured to cause disturbances within a fluid flowing through the buffer vessel. In other words, the apparatus is configured for performing a method as just described.

[0011] Specifically, the second fluid metering device (or at least one of the fluid metering devices) is configured to provide the second amount such that the second amount is less than 1%, 0.3%, 0.1%, 300 ppm, 100 ppm, 30 ppm, 10 ppm, 3 ppm, 1 ppm, 300 ppb or less than 100 ppb, in relation to the total amount of the mixed fluid by volume or mass, respectively. This is a concentration regime, which poses particularly difficult challenges in terms of homogenization.

[0012] In advantageous embodiments, the filling of the buffer vessel comprises one or more selected from the group consisting of fibres, particularly comprising metal and/or glass and/or carbon and/or polymeric fibres, perforated sheet material, coarse-grained particulate material, foams, macroporous material and structured substrate. Those are particularly well suited fillers for causing disturbances without causing an inacceptably high pressure drop.

[0013] The filling may take up a volume in the range

of 0.5% to 99.5% of the buffer vessel's inner volume, particularly in the range of 5% to 95%, more particularly in the range of 10% to 75%, preferably in the range of 25% to 50%. The specific range may be chosen depending on the filler material used and/or according to the desired homogeneity and/or the maximum acceptable pressure drop.

[0014] Particularly, the buffer vessel has a volume of less than 100 L (litres), particularly in the range of 0.1 L to 10 L, preferably in the range of 0.5 L to 2 L. The buffer vessel preferably has a volume of less than 20%, particularly less than 10%, preferably less than 5%, of the volume of the mixing vessel. In some embodiments, the buffer vessel has a volume, which corresponds to less than 10%, preferably less than 5%, 2% or 1% of the amount of mixed fluid flowing through the mixing vessel during operation within a time of 1 s or 1 min. Such a small buffer volume was found to be sufficient for a favourable homogenization effect and does not cause a drastically spatial footprint or investment costs of the apparatus as a whole.

[0015] In advantageous embodiments, the homogenizer comprises a heater configured to heat a gas flowed through the buffer vessel. As already explained above, this aids accelerate the homogenization process within the buffer vessel.

[0016] A homogenizer for an apparatus according to the invention comprises a buffer vessel with a filling configured to cause disturbances in a fluid flowed there-through.

Brief description of the drawings

[0017] Figure 1 shows an advantageous embodiment of the invention in the form of a simplified block diagram

Embodiment(s) of the invention

[0018] In the following, the invention is explained in further detail with reference to the appended drawing. In the drawing, reference numerals used for referring to a component of an embodiment of an apparatus according to the invention may also be used to refer to a method step carried out within the respective apparatus component or vice versa.

[0019] In Figure 1, an advantageous embodiment of the invention is schematically depicted and collectively referred to with the numeral 100.

[0020] An apparatus 100, as depicted in Figure 1, comprises a mixing vessel 130 in fluid connection with a first metering device 110 and a second metering device 120, both of which are provided upstream the mixing vessel 130. It is to be noted, that the mixing vessel 130 is depicted in an enlarged manner so as to better discern certain details. The mixing vessel 130 may be provided in the form of a duct or piping, which does not differ in diameter from any other piping used elsewhere within the apparatus 100.

[0021] Downstream the mixing vessel 130, a homogenizer 140 is provided.

[0022] The first and second metering devices 110, 120 are each configured to provide a desired amount of a fluid, especially a gas, to the mixing vessel 130. In the example shown, the metering devices 110, 120 are valves, which may be controlled by a control unit 150.

[0023] The first valve 110 is configured to provide a large amount of a first gas 1 to the mixing vessel 130, while the second valve 120 is configured to provide a comparatively very small amount of a second gas 2 to the mixing vessel 130. Both of the valves 110, 120 are very precise in their respective working range such that the concentration of the two gases 1, 2 within the mixing vessel 130 may be precisely adjusted. For example, the concentration of the second gas 2 within a mixed gas 3 produced in the mixing vessel 130 from the two gases 1, 2 may be in the ppm range and may be chosen with a precision in the ppb range such that a relative error in concentration of the second gas 2 may be smaller than 1%, for example. The homogenization provided by this invention ensures, that the concentration chosen with the metering devices is evenly distributed across the entirety of the mixed fluid. Without this homogenization, fluctuations in concentration across the volume of the mixed fluid may be much higher than the error margin stated above.

[0024] The mixing vessel 130 in the depicted example is provided with guide plates therein in order to enhance the mixing of the two gases 1, 2 therein. It is to be noted, that the mixing vessel 130 does not need to be provided in the form of a tank, as depicted, but may also be provided in the form of one or more pipes or any other suitable form. Same is true for the buffer vessel 142, which might be in the form of one or more pipes or any other suitable form. The buffer vessel 142 may be directly at the exit outside of, or even inside, the mixing vessel 130, or further downstream of the mixing vessel, e.g. as a last component before a storage tank or before the consumer of the gas mixture.

[0025] The mixed gas 3 is sent to the homogenizer 140 downstream the mixing vessel 130. The homogenizer 140 comprises a buffer vessel 142 with a filling 144 which is configured to cause disturbances within the mixed gas 3 flowing through the buffer vessel 140. The buffer vessel 142 is very small in comparison to the mixing vessel 130, e.g. it exhibits a volume corresponding to less than 10% of the volume of the mixing vessel 130. In a particularly advantageous embodiment, the buffer vessel 142 has a volume in the range of 0.5 L to 2 L. Preferably, the volume of the buffer vessel 142 is chosen in relation to a fluid flow rate. For example, the buffer vessel may have a volume, which corresponds to less than 10%, preferably less than 5%, 2% or 1% of the amount of mixed fluid 3 flowing through the mixing vessel 130 during operation within a time of 1 s or 1 min. It was found that even with such a small volume, the homogeneity of the so homogenized mixed gas 4 was sufficiently improved in compar-

ison to apparatuses without the homogenizer.

[0026] The filling 144 of the homogenizer 140 may, for example, be provided in the form of fibrous material such as steel wool, glass fibres or the like. Other suitable fillings include perforated steel plates, particularly with non-aligned perforations, foams or coarse grained particulate materials, such as steel balls, in order to cause multiple changes in flow direction within the mixed gas 3 upon passing through the filling 144. The filling 144 may be chosen depending on the specific gases 1, 2 to be mixed, especially in cases where at least one of the gases 1, 2 comprises corrosive or otherwise chemically reactive species.

[0027] In some embodiments, the homogenizer 140 may comprise a heater (not shown in the Figure) configured to heat the mixed gas 3 flowing through the buffer vessel 142. This increases a rate of diffusion within the mixed gas 3, thereby accelerating the homogenization process. For example, the mixed gas 3 within the buffer vessel 142 may be heated to a temperature in the range between 50 °C to 200 °C, particularly in the range between 50 °C and 100 °C. Obviously, this temperature range may be chosen according to the concrete fluids 1, 2, mixed within the apparatus 100. For example, some chemical species may be prone to decomposition under elevated temperature conditions such that in such cases, a lower temperature may be chosen than in cases in which only thermally stable fluids 1, 2 are mixed with one another.

[0028] However, in some cases, for example when the concentration of the second gas 2 within the mixed gas 3 is set to be higher, e.g. more than 1% by volume, the homogenizer 140 may not be necessary in order to achieve sufficient homogeneity. Therefore, control valves 146, 148 may be used to bypass the homogenizer in such cases to provide the mixed gas 3 directly to downstream processes or a storage tank without passing the homogenizer 140.

[0029] The described solution is particularly useful for very low concentrations of one or more gas components 2, but may also be helpful in homogenizing mixed gases 3 in which the first and second components 1, 2 exhibit large differences in density, for example. The described approach is, of course, also suitable for mixed gases 3 comprising more than two components 1, 2. In such cases, more metering devices 110, 120 may be provided.

Claims

1. Method of mixing at least a first fluid (1) and a second fluid (2) with one another, the method comprising

providing the first fluid (1) in a desired first amount to a mixing vessel (130) having a first volume,
providing the second fluid (2) in a desired second amount to the mixing vessel, affording a

mixed fluid (3), and

flowing the mixed fluid (3) through a homogenizer (140) comprising a buffer vessel (142) with a second volume and a filling (144) within the buffer vessel (142), thereby thoroughly mixing the first (1) and second (2) fluids with one another to afford a homogenized mixed fluid (4).

2. Method according to claim 1, wherein the first fluid (1) and the second fluid (2) are gases.

3. Method according to claim 1 or 2, wherein the second amount is in the range of less than 1 %, 0.3 %, 0.1 %, 300 ppm, 100 ppm, 30 ppm, 10 ppm, 3 ppm, 1 ppm, 300 ppb or less than 100 ppb, in relation to the total amount of the mixed fluid by volume or mass, respectively.

4. Method according to any of the preceding claims, wherein the filling (144) of the buffer vessel (142) is configured to cause disturbances within the mixed gas (3) flowed through the buffer vessel (142).

5. Method according to any of the preceding claims, wherein the mixed gas (3) is heated within the buffer vessel (142).

6. Apparatus (100) for mixing at least a first fluid (1) and a second fluid (2) with one another, comprising

a mixing vessel (130), configured to receive at least the first (1) and the second (2) fluid and to produce a mixed fluid (3) therefrom,

a first fluid metering device (110), configured to provide a desired first amount of the first fluid (1) to the mixing vessel (130),

a second fluid metering device (120), configured to provide a desired second amount of the second fluid (2) to the mixing vessel (130), and

a homogenizer (140) downstream of the mixing vessel (130), the homogenizer (140) comprising a buffer vessel (142) with a filling (144), wherein the filling (144) is configured to cause disturbances within a fluid (3) flowing through the buffer vessel (142).

7. Apparatus (100) according to claim 6, wherein the first (1) and the second (2) fluids are gases.

8. Apparatus (100) according to claim 6 or 7, wherein the second fluid metering device (120) is configured to provide the second amount such that the second amount is less than 1%, 0.3%, 0.1%, 300 ppm, 100 ppm, 30 ppm, 10 ppm, 3 ppm, 1 ppm, 300 ppb or less than 100 ppb, in relation to the total amount of the mixed fluid (3) by volume or mass, respectively.

9. Apparatus (100) according to any of claims 6 through

8, wherein the filling (144) of the buffer vessel (142) comprises one or more selected from the group consisting of fibres, particularly comprising metal and/or glass and/or carbon and/or polymeric fibres, perforated sheet material, coarse-grained particulate material, foams, macroporous material and structured substrate.

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10. Apparatus (100) according to any of claims 6 through 9, wherein the filling (144) takes up a volume in the range of 0.5% to 99.5% of the buffer vessel's (142) inner volume, particularly in the range of 5% to 95%, more particularly in the range of 10% to 75%, preferably in the range of 25% to 50%.

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11. Apparatus (100) according to any one of claims 6 through 10, wherein the buffer vessel (142) has a volume of less than 100 L, particularly in the range of 0.1 L to 10 L, preferably in the range of 0.5 L to 2 L.

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12. Apparatus (100) according to any of claims 6 through 11, wherein the buffer vessel (142) has a volume of less than 20%, particularly less than 10%, preferably less than 5%, of the volume of the mixing vessel (130) and/or wherein the buffer vessel (142) has an inner volume corresponding to less than 10% or less than 5%, 2% or 1 % of a maximum volume of mixed gas (3) passing through the mixing vessel (130) during operation of the apparatus (100) within 1 s or 1 min.

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13. Apparatus (100) according to any of claims 6 through 12, wherein the homogenizer (140) comprises a heater configured to heat a gas (3) flowed through the buffer vessel (142).

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14. Homogenizer (140) for an apparatus (100) according to any of claims 5 through 11, the homogenizer (140) comprising a buffer vessel (142) with a filling (144) configured to cause disturbances in a fluid (3) flowed therethrough.

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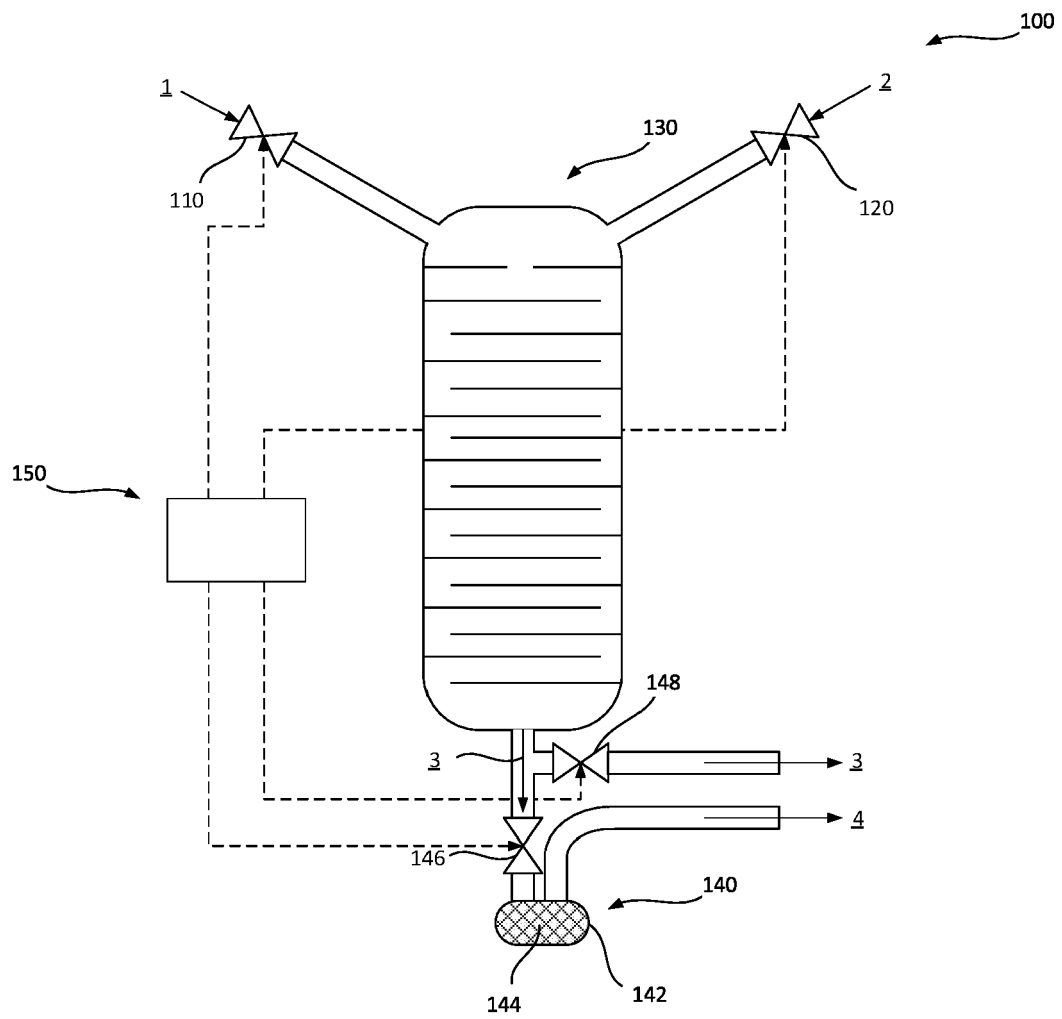


Fig. 1



EUROPEAN SEARCH REPORT

Application Number

EP 22 02 0111

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A	* page 1, line 10 - line 14 * * page 1, line 27 - line 50 * * page 1, line 86 - page 2, line 45 * * figures *	5, 13	
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			TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 9 September 2022	Examiner Real Cabrera, Rafael
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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