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(54) Title: METHOD AND ARRANGEMENT FOR REMOVING PARTICLES FROM EXHAUST GAS

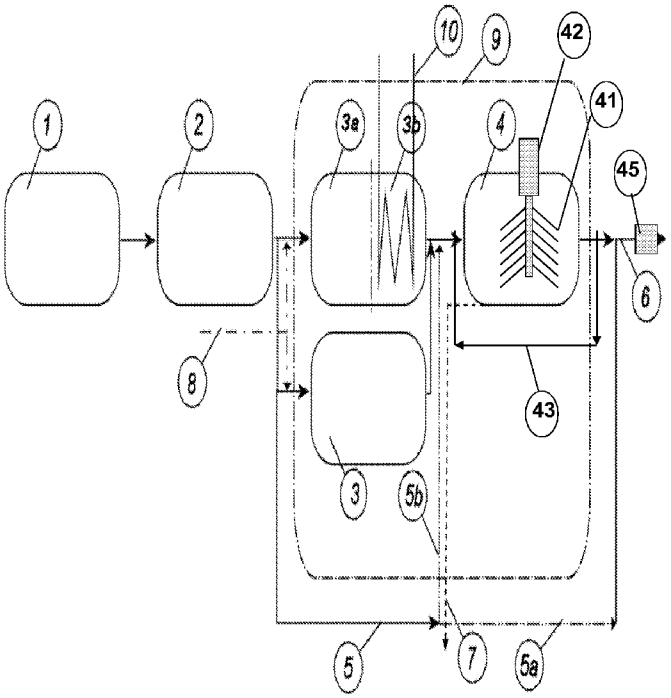

FIG. 4

(57) Abstract: The invention relates to a method for removing particles from exhaust gas from an exhaust gas flow of an internal combustion engine (1). The exhaust gas from an internal combustion engine (1) is led to an exhaust gas particle cleaning device (9). In order to allow for efficient particle removal (4) from the exhaust gas, water supersaturation is provided in the exhaust gas particle cleaning device (9). The exhaust gas particle cleaning device is provided with a low pressure section (3a) and a high pressure section (3b) causing particle growth at the high pressure section (3b).

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Method and arrangement for removing particles from exhaust gas

Technical field

The present invention relates to a method for removing particles from exhaust gas, in which method an exhaust gas flow from an internal combustion engine is led to an exhaust gas particle cleaning device according to the preamble of claim 1. The present invention also relates to an arrangement for removing particles from exhaust gas according to claim 11.

Background art

Exhaust gases are normally cleaned by catalyst devices, but the presently available catalyst devices do not remove particles. Exhaust gas particles, particularly in diesel engine exhaust gases, are generally smaller than 0.1 µm in size, typically below 0.2 µm. Particles of this size class are extremely difficult to remove because of the negligible mass of the particles. In the vehicle industry, particles of this size are removed by filters, whereby deposited particles are removed by burning them off the filter. However, if particles contain a high fraction of ash, as when burning heavy fuel oil, deposits cannot be removed by burning them off the filter. Particles, much larger than normally found in diesel engine exhaust gases, can be removed by other means than filtration.

Summary of invention

An object of the invention is to avoid the disadvantages of prior art and to achieve a method which provides for a sufficient particle size for removal and for removal of large numbers of particles normally contained in an exhaust gas flow. This object is attained by a method according to claim 1.

The basic idea of the invention is to introduce the exhaust gas flow from an internal combustion engine, e.g. a diesel engine, into an exhaust gas particle cleaning device in which water supersaturation is present, whereby particles are grown to a larger size for removal. The exhaust gas particle cleaning device is

provided with a low pressure section and with a high pressure section causing particle growth at the high pressure section. The grown particles can then be removed from the exhaust gas particle cleaning device.

In order to achieve a given particle growth it is advantageous that the residence time of the exhaust gas in the exhaust gas particle cleaning device is kept sufficiently long.

The advantageous features of the method according to the present invention are given in claims 2 – 10. The main and advantageous features of the arrangement according to the present invention are given in claims 12 – 16.

Brief description of drawings

In the following the invention will be described, by way of example only, with reference to the accompanying drawings, in which

Figures 1-4 illustrate different embodiments of the arrangement of the present invention.

Detailed description

According to an embodiment of the present invention, as shown in Figures 1-3, an exhaust gas flow from an internal combustion engine 1, e.g. a diesel engine, is led an exhaust gas particle cleaning device 9. Advantageously, the exhaust gas flow is firstly introduced into a catalyst device 2, since a catalyst device generally requires a higher temperature.

In the exhaust gas particle cleaning device 9 supersaturation is achieved by means of changes in pressure. This is done by providing the exhaust gas particle cleaning device with a low pressure section and high pressure section causing particle growth at the high pressure section. Isothermic difference between low pressure and high pressure should be 50 – 200mBar in order to achieve sufficient particle growth. These pressure values are is strongly dependent on temperature of the exhaust gas. The required pressure increase can be

achieved e.g. by means of a pressure pump. The particles can be grown to different sizes for efficient removal.

Exhaust gas particles from diesel engines are composed of solid particles and volatile compounds. The solid particles are composed of carbon and ash components of fuel and lube oil. The volatile compounds generally consist of some unburned fuel, lube oil and sulphuric acid. In order to reach high efficiency in particle removal, both the solid particles and the volatile compounds have to be removed.

The exhaust gas particle cleaning device 9 advantageously comprises two parts, a first part 3 for particle growth and a second part 4 for particle removal. In this way the first part 3 for particle growth can be provided with the low pressure section and the high pressure section. The second part 4 is advantageously a centrifugal mist separator. The principle of the centrifugal mist separator is illustrated in figure 4.

The first part 3 for particle growth is arranged before, i.e. upstream of the second part 4 for particle growth in the direction of the exhaust gas flow. The advantage of having a first part 3 for particle growth and separate second part for particle removal allows for adapting the second part 4 for particle removal to prevailing particle size, i.e. the particle size achieved in the first part 3. The exhaust gas flow is firstly introduced into the first part 3 and then further led to the second part 4.

In such a two-part exhaust gas particle cleaning device, supersaturation is maintained in the first part 3 for particle growth of the exhaust gas particle cleaning device. Line 8 indicates a water supply or water vapour supply to the first part 3. The water vapour is brought to supersaturation by changes in pressure, whereby particle growth commences in the first part 3.

Preferably all particles are grown to a given desired particle size. Particles can also be grown to different sizes. In order to initiate required particle growth there is sufficiently long residence time of the exhaust gas in the exhaust gas particle cleaning device, i.e. in the first part 3 of a two-part exhaust gas particle cleaning

device. Consequently, a desired given particle growth can be achieved by keeping the residence time long enough. Residence time of the exhaust gas in the exhaust gas particle cleaning device 9 can be adjusted by changing the flow rate in the first part 3. This can be achieved by guiding portion of the exhaust gas pass the first part 3 and/or by increasing the number of first part 3 units.

Grown particles can also be mixed with un-grown particles in order to enhance coagulation and consequently to provide for optimal removal. Optimal removal is achieved by matching particle growth in the first part 3 to particle removal efficiency in the second part 4. Particles of a size smaller than optimal or adequate removal capability of the second part 4 are grown in first part 3. Smaller particles are grown faster than larger ones in water supersaturation that is provided in the exhaust gas particle cleaning device. Therefore it is possible to increase the amount of particles having the size within the range removal capability of the second part 4. Preferably the amount of particles having the size of 0,1 – 1,0 µm is increased in the first part 3 and more preferably the amount of particles having the size of 0,3 – 0,8 µm is increased in the first part 3. This has an advantage in that devices for the second part 4 for removal can be selected more advantageously in view of cost, size, availability etc.

Depending on the degree of particle cleaning requirement the number of exhaust gas particle cleaning devices 9 may vary. They can be arranged in parallel, whereby an exhaust gas flow or a part of an exhaust gas flow can be introduced to the/each exhaust gas particle cleaning device 9 in order to achieve a required degree of particle cleaning, i.e. in order to achieve an appropriate emission level. The cleaned exhaust gas flow or parts of the cleaned exhaust gas flows can be combined with each other, or even with an un-cleaned exhaust gas flow, depending on the desired emission level.

In the following some examples of the arrangement according to the present invention will be discussed more in detail. Clearly, other combinations of the different components, internal combustion engines, catalyst devices, exhaust gas particle cleaning devices, first parts and second parts, as well as exhaust gas flow patterns may vary.

In Figure 1 the exhaust gas from an internal combustion engine 1 is firstly led to a catalyst device 2 and then to the first part 3 and subsequently to the second part 4 of the exhaust gas particle cleaning device. Line 5 indicates a by-pass flow, with respect to the exhaust gas particle cleaning device, of the exhaust gas. In this embodiment there are two first parts 3 and two second parts 4. Portion of the exhaust gas flow is arranged to by-pass the first part 3. Particles that are grown in the first part 3 are mixed with un-grown particles after the second part 4 or before the second part 4 as indicated with reference numbers 5a and 5b, respectively. Broken line 7 from the second part 4 indicates the removal of water including extracted particles. Line 6 indicates the final exhaust gas flow that has been cleaned, and which also may be combined with the by-pass flow 5.

In Figure 2 the exhaust gas from an internal combustion engine 1 is firstly led to a catalyst device 2 and then to the first part 3 and subsequently to the second part 4 of the exhaust gas particle cleaning device. Line 5 indicates a by-pass flow, with respect to the exhaust gas particle cleaning device, of the exhaust gas. In this embodiment there are two first parts 3 and one second part 4, whereby an arrow line indicates that the exhaust gas from the second first part 3 is led to said one second part 4. Portion of the exhaust gas flow is arranged to by-pass the first part 3. Particles that are grown in the first part 3 are mixed with un-grown particles after the second part 4 or before the second part 4 as indicated with reference numbers 5a and 5b, respectively. Broken line 7 from the second part 4 indicates the removal of water including extracted particles. Line 6 indicates the final exhaust gas flow that has been cleaned, and which also may be combined with the by-pass flow 5.

In Figure 3 the exhaust gas from an internal combustion engine 1 is firstly led to a catalyst device 2 and then to the first part 3 and subsequently to the second part 4 of the exhaust gas particle cleaning device. Line 5 indicates a by-pass flow, with respect to the exhaust gas particle cleaning device, of the exhaust gas. In this embodiment there is one first part 3 and two second parts 4, whereby an arrow line indicates that the exhaust gas from said one first part 3 is also led to the other second part 4. Portion of the exhaust gas flow is arranged

to by-pass the first part 3. Particles that are grown in the first part 3 are mixed with un-grown particles after the second part 4 or before the second part 4 as indicated with reference numbers 5a and 5b, respectively. Broken line 7 from the second part 4 indicates the removal of water including extracted particles. Line 6 indicates the final exhaust gas flow that has been cleaned, and which also may be combined with the by-pass flow 5a.

In Figure 4 the principle of the centrifugal mist separator 4 is illustrated. The centrifugal mist separator 4 comprises a motor 42 which is arranged to rotate a disk stack 41, i.e. rotatable exhaust guiding part. Exhaust gas is guided to centre of the disk stack 41 and exits between disks of the disk stack 41. Speed of the exhaust gas flow is increased by rotating a disk stack 41 in the centrifugal mist separator.

Another alternative is centrifugal mist separator where a motor which is arranged to rotate a rotatable exhaust guiding part comprising two co-axial pipes. Exhaust gas is guided between pipes. At least one of the pipes is rotated such that centrifugal forces are applied by a motor.

Residence time of the exhaust gas in the exhaust gas particle cleaning device 9 can therefore also be adjusted by speed of the motor of the centrifugal mist separator 4. The arrangement further comprises a return line 43 from location after the centrifugal into location between the lower temperature section 3b and the centrifugal mist separator 4. The return line 43 allows recirculation of the exhaust gas from location after the centrifugal into location between the lower temperature section 3b and back to the centrifugal mist separator 4.

The arrangement further comprises device for exhaust gas measurement 45. The speed of the motor 42 of the centrifugal mist separator 4 can be partly or fully controlled based on this exhaust gas measurement 45.

Clearly also a one-part exhaust gas particle cleaning device can be used.

The description is intended to clarify the basic idea of the invention. The invention may vary in detail within the scope of the ensuing claims.

Claims

1. Method for removing particles from exhaust gas from an internal combustion engine (1), in which method an exhaust gas flow from an internal combustion engine (1) is led to an exhaust gas particle cleaning device, providing water supersaturation in the exhaust gas particle cleaning device (9), the exhaust gas flow is introduced into the exhaust gas particle cleaning device provided with a low pressure section (3a) and high pressure section (3b) causing particle growth at the high pressure section, **characterised** in that grown particles are removed from the exhaust gas flow in a centrifugal mist separator (4)..

2. Method according to claim 1, **characterised** in that speed of the exhaust gas flow is increased by rotating a disk stack (41) in the centrifugal mist separator (4) with a motor (42).

3. Method according to claim 1 or 2, **characterised** in that portion of the exhaust gas is recirculated from location after the centrifugal into location between the lower temperature section (3b) and the centrifugal mist separator (4).

4. Method according to claim 1 - 3, **characterised** in that residence time of the exhaust gas in the exhaust gas particle cleaning device (9) is adjusted by speed of the motor of the centrifugal mist separator (4).

5. Method according to any previous claim, **characterised** in that residence time of the exhaust gas in the exhaust gas particle cleaning device (9) is adjusted by guiding portion of the exhaust gas to pass the higher temperature section (3a) and the lower temperature section (3b).

6. Method according to any previous claim, **characterised** in that method further comprises exhaust gas measurement and speed of the motor (42) of the centrifugal mist separator (4) is controlled based on this exhaust gas measurement (45).

7. Method according to claim 1, **characterised** in that the method employs an exhaust gas particle cleaning device with a first part (3) for particle growth, in which the particles are grown, and a second part (4) for particle removal, from

which the grown particles are removed, and in that the exhaust gas flow is introduced into the first part (3) and subsequently led to the second part (4).

8. Method according to any previous claim, **characterised** in that amount of particles having the size of 0,1 – 1,0 µm is increased in the first part (3).

9. Method according to any previous claim 1 – 6, **characterised** in that amount of particles having the size of 0,3 – 0,8 µm is increased in the first part (3).

10. Method according to any previous claim, **characterised** in that the exhaust gas flow is firstly introduced into a catalyst device (2).

11. Arrangement for removing particles from exhaust gas from an exhaust gas flow of an internal combustion engine (1), which arrangement comprises at least one first part provided with a low pressure section (3a) and a high pressure section (3b), the high pressure section (3b) causing particle growth and at least one second part for particle removal **characterised** in that the second part for particle removal is a centrifugal mist separator (4).

12. Arrangement according to claim 11, **characterised** in that the centrifugal mist separator (4) comprises a motor (42) arranged to rotate a disk stack (41).

13. Arrangement according to claim 11 or 12, **characterised** in that the exhaust gas particle cleaning device comprises a first part (3) for particle growth and a second part (4) for particle removal, and in that the first part (3) is arranged before the centrifugal mist separator (4) in the direction of the exhaust gas flow.

14. Arrangement according to claim 11 – 13 , **characterised** in that a catalyst device (2) is arranged before the exhaust gas particle cleaning device (9).

15. Arrangement according to claims 11 – 14, **characterised** in that the arrangement further comprises device for exhaust gas measurement (45) and speed of the motor (42) of the centrifugal mist separator (4) is controllable based on this exhaust gas measurement (45).

16. Arrangement according to claims 11 – 15, **characterised** in that the arrangement further comprises a return line (43) from location after the centrifugal into location between the lower temperature section (3b) and the centrifugal mist separator (4).

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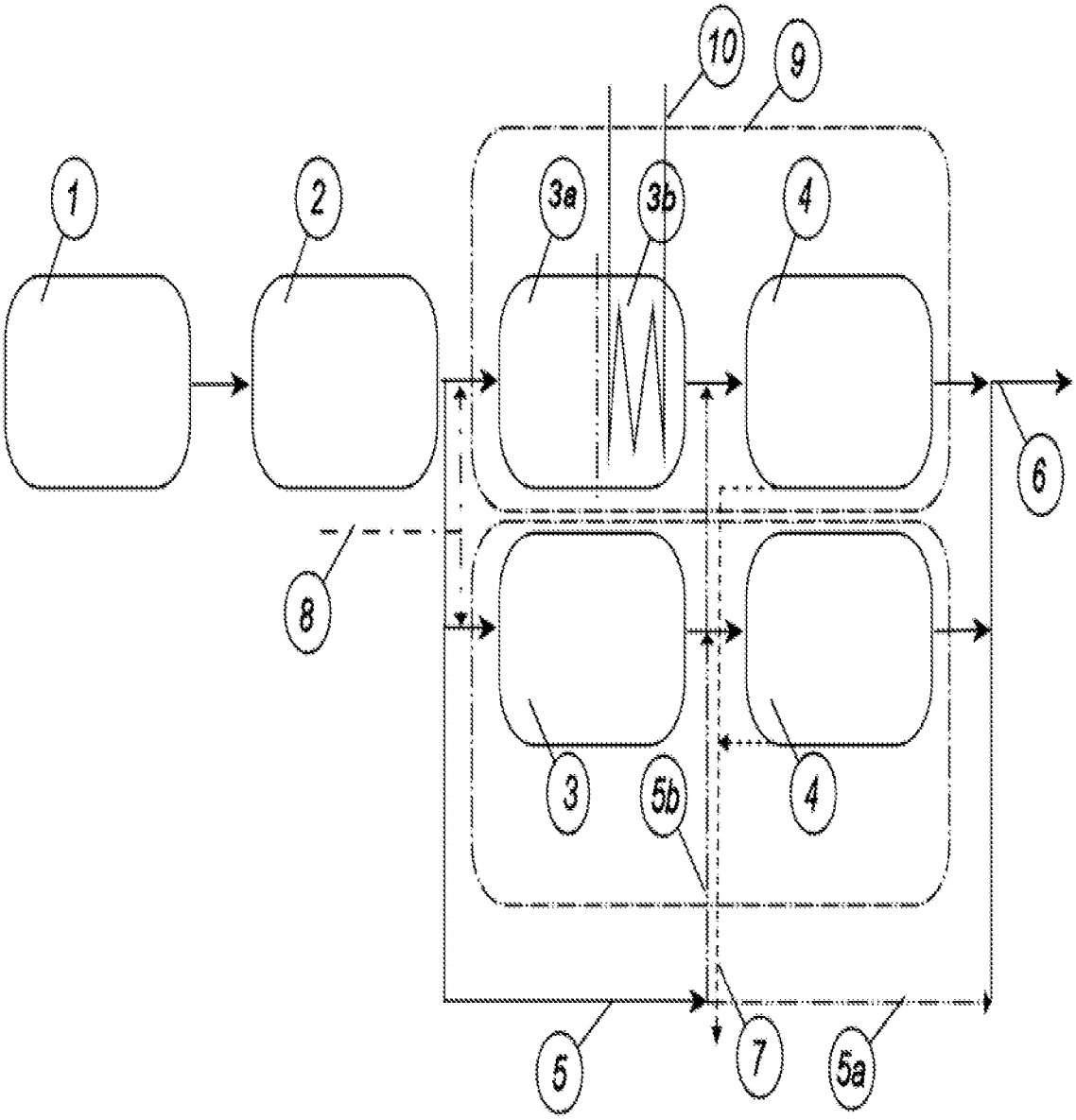

FIG. 1

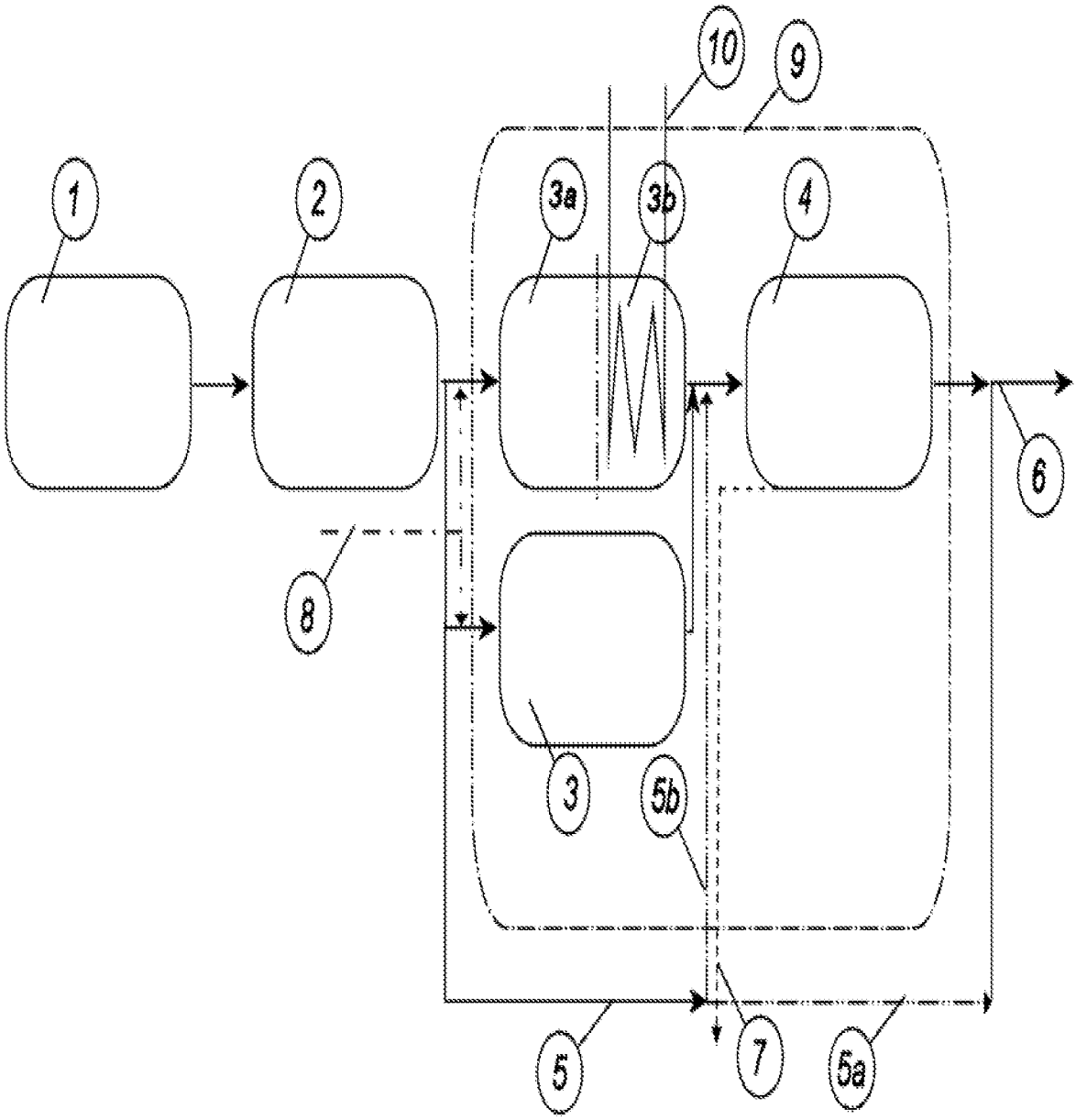

FIG. 2

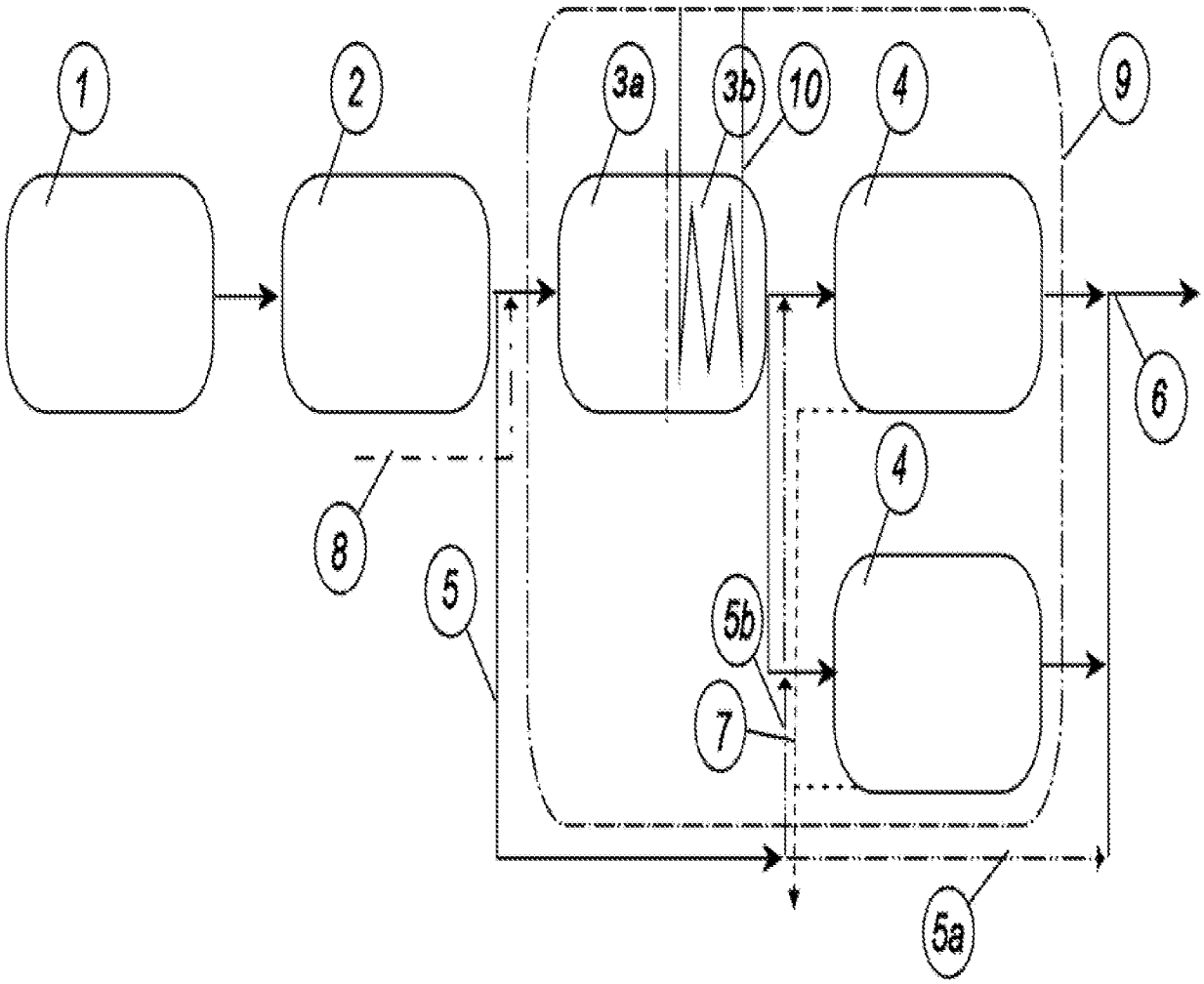

FIG. 3

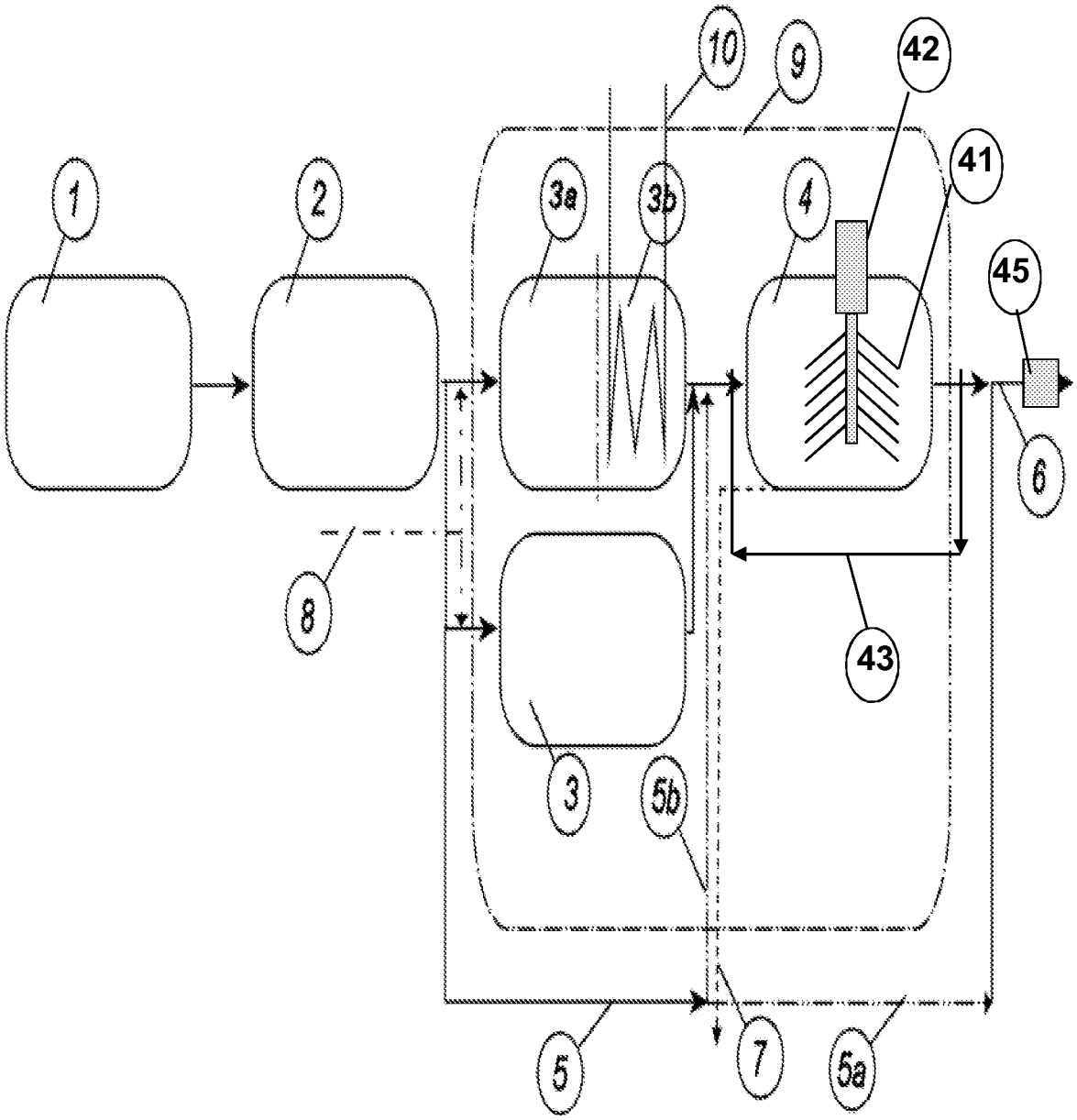

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2009/050992

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F01N, B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5176723 A (LIU ET AL), 5 January 1993 (05.01.1993), column 2, line 33 - column 3, line 8; column 3, line 52 - line 55; column 6, line 47 - line 53	1-16
X	WO 9956854 A1 (TOUBORG, JORN), 11 November 1999 (11.11.1999), page 1, line 8 - line 17; page 1, line 28 - page 2, line 16	1-16
X	US 5281245 A (YANG), 25 January 1994 (25.01.1994), column 4, line 26 - line 35; column 7, line 54 - line 68; column 9, line 33 - line 40, figure 1	1,11

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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INTERNATIONAL SEARCH REPORT

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 20050142052 A1 (ROSEN), 30 June 2005 (30.06.2005), figures 3-6, paragraphs (0006), (0017),(0018)	1-16
A	WO 2007094725 A1 (ALFA LAVAL CORPORATE AB), 23 August 2007 (23.08.2007), page 5, line 34 - page 6, line 24, figure 1	2,4,6,12,15

INTERNATIONAL SEARCH REPORT

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Cited literature, if any, will be enclosed in paper form.

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