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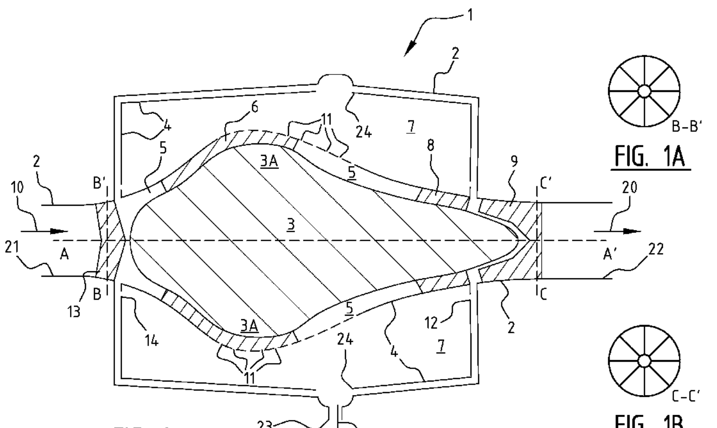

FIG. 1

(57) Abstract: The present invention provides an apparatus (1) for removing a contaminant from a contaminated stream (10), the apparatus (1) at least comprising: - a housing (2) having an inlet (21) for a contaminated stream (10), a first outlet (22) for a contaminant- depleted stream (20) and a second outlet (23) for a contaminant-enriched stream (30); - an inner body (3) arranged in the housing (2); - an outer body (4) arranged in the housing (2) and around the inner body (3), which outer body (4) is mounted for rotation in the housing (2) around a rotation axis (A-A'), wherein the inner body (3) and the outer body (4) define an annular flow path (5) between them; - a swirl generator (6,13) for inducing a swirling flow in the annular flow path (5) between the inner body (3) and the outer body (4); - a swirl reducer (8,9) for reducing a swirling flow in the annular flow path (5) between the inner body (3) and the outer body (4); • wherein the inner body (3) has a protrusion (3A) facing towards the outer body (4), and • wherein the outer body (4) comprises a chamber (7) for receiving a contaminant, the chamber (7) being fluidly connected to the annular flow path (5) between the inner body (3) and the outer body (4).

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APPARATUS AND METHOD FOR REMOVING A CONTAMINANT FROM A CONTAMINATED STREAM

The present invention relates to an apparatus and method for removing a contaminant from a contaminated stream, in particular a contaminated gas stream.

Various methods are known to remove contaminating components, such as water, liquid hydrocarbons (also called “condensate”), hydrates, carbon dioxide (CO_2) and/or hydrogen sulphide (H_2S), from a gas stream such as a natural gas stream. The methods may be based on physical and/or chemical separation techniques. Physical separation techniques use differences in e.g. boiling, condensation and/or freezing points of the various contaminating components to selectively remove one or more of these components in a fractionating column, or differences in density to separate components with different densities by gravity (e.g. gravity settler), by a swirling flow (e.g. in a cyclonic separator) or by spinning flow (e.g. in a centrifugal separator). Chemical separation techniques may employ selective absorption or catalytic reactions to convert a contaminating component into a composition that can be easily separated.

WO 95/24959 discloses a process and device for the pollution control of combustion processes by removal of nitrogen oxides from combustion gas, i.e. gas/gas separation.

GB 237 617 discloses a method and apparatus for promoting the separation of mixtures of gases and vapours into fraction of different molecular weights, i.e. gas/gas or gas/vapour separation.

There is a constant desire for new and alternative apparatuses and methods for removing contaminants from a contaminated stream.

It is an object of the present invention to provide an apparatus and method for removing a contaminant from a contaminated stream, in particular a contaminated gas stream, in an efficient and economical manner, even if the contaminated stream comprises a large fraction (such as >20 vol.%) of contaminants.

It is a further object of the present invention to provide an apparatus and method for removing a liquid contaminant from a gaseous contaminated stream, in particular a contaminated gas stream.

It is an even further object of the present invention to provide an alternative system and method for removing H_2O, liquid hydrocarbons, CO_2 and/or H_2S, etc. from a gas stream.

One or more of the above or other objects are achieved according to the present invention by providing an apparatus for removing a contaminant from a contaminated stream, the apparatus at least comprising:

- a housing having an inlet for a contaminated stream, a first outlet for a contaminant-depleted stream and a second outlet for a contaminant-enriched stream;
- an inner body arranged in the housing;
- an outer body arranged in the housing and around the inner body, which outer body is mounted for rotation in the housing around a rotation axis, wherein the inner body and the outer body define an annular flow path between them;
- a swirl generator for inducing a swirling flow in the annular flow path between the inner body and the outer body;

- a swirl reducer for reducing a swirling flow in the annular flow path between the inner body and the outer body;

wherein the inner body has a protrusion facing towards the outer body, and

wherein the outer body comprises a chamber for receiving a contaminant, the chamber being fluidly connected to the annular flow path between the inner body and the outer body.

An advantage of the present invention is that contaminants can be removed in an efficient and economical manner, requiring only a very low level of maintenance.

A further advantage of the present invention is that a swirling motion of the stream to be separated is created (and subsequently reduced), whilst mixing and turbulence is kept at a minimum.

The contaminated stream is not limited in any way (in terms of composition, phase, etc.) and may for example be a natural gas stream, a combustion gas, synthesis gas, an air stream, etc. Typically (and preferably) the contaminated stream is a multiphase stream, i.e. containing at least two phases, preferably containing gas and a contaminant being solid and/or liquid under the operating conditions. However, more generally, the contaminated stream may comprise at least two components having a different density (a relatively low one and a relatively high one, such as oil and water) which components are separated based on the difference in density.

Preferably, the contaminated stream is a methane-rich stream such as natural gas, containing at least 30 wt.% methane, preferably at least 50 wt.% methane.

The person skilled in the art will readily understand that the contaminant is not limited to certain compounds and may include a broad variety of compounds. However, the present invention is in particular suitable for the removal of H_2O, liquid hydrocarbons, CO_2 and/or H_2S from a contaminated gas stream such as natural gas or a combustion gas.

The housing is not limited in any way. Typically, the housing ensures that no undesired leakage of the contaminated stream, or components thereof, occurs. Preferably, the housing is a stationary housing, i.e. it does not move during use.

Also, the inner body and the outer body are not limited in any way. Typically, the inner body is elongated along the rotation axis around which the outer body (and in some embodiments the inner body as well) rotates. The inner body may be massive or hollow. In some embodiments the outer body may rotate around the inner body during use, whilst the inner body remains in a fixed position. However, it is preferred that the inner body can rotate around the (same) rotation axis of the outer body. The inner body may rotate around the rotation axis in the same or opposite direction, but preferably in the same direction. Preferably, the inner body and the outer body are attached to each other; in the latter case the inner body and outer body co-rotate during use. The inner body and outer body may be attached to each other in various ways; as mere examples, the inner body and outer body may be attached to each other at one or more of the swirl generator and the swirl reducer (discussed hereinafter).

Typically, during use the outer body rotates around the rotation axis with a speed in the range of from 100 to 15,000 rpm. The rotation of the outer body and, where applicable, the inner body may be achieved in various ways by either an active drive system (which may be mechanically, electrically, pneumatically, hydraulically, chemically, magnetically, etc.) or a passive drive system using the flow (in which the rotational motion is achieved by means of the flow).

The inner body has a protrusion facing towards the outer body; preferably, the protrusion has an aerodynamic shape (to avoid or at least minimize boundary layer separation and turbulence). Although the outer body may follow the shape of the inner body to some extent, the protrusion narrows the annular flow path between the inner body and the outer body locally. Preferably, the protrusion is an axisymmetric (and preferably also annular) protrusion, in particular with respect to the rotation axis around which (at least) the outer body rotates during use. Preferably, the inner body is wider at the protrusion than at the parts thereof near the inlet and the first outlet of the housing. Typically, the inner body has (if the inner body has one protrusion) a somewhat blunt nose, a section of increasing radius (as seen from the rotation axis), a section of maximum radius and a section of decreasing radius (see also Fig. 1 hereinafter). In the section where the radius of the inner body and outer body are decreasing, the swirling component of velocity will increase in magnitude due to conservation of angular momentum; this increasing swirl velocity enhances the separation performance.

As mentioned above, the outer body comprises a chamber for receiving a contaminant, the chamber being fluidly connected to the annular flow path between the inner body and the outer body, by means of one or more openings in a wall of the outer body facing the annular flow path. This chamber is not limited in any way.

Typically, the outer surfaces of the outer body function as the walls of the chamber. Since the chamber is rotating with the outer body during use of the apparatus, the chamber acts as a centrifuge.

The swirl generator for inducing a swirling flow in the annular flow path between the inner body and the outer body is not limited in any way either. Examples of swirl generators that can be used are guide vanes, wing-like structures, structures containing one or more sharp edges, deflection vanes for generating vortices (e.g. having a V-shape, diamond-shape, half delta shape, chevron-shape) and curvilinear structures (e.g. having a helical surface), etc.

In one preferred embodiment, the swirl generator is arranged in the annular flow path between the inner body and the outer body, preferably upstream of the protrusion of the inner body. In an especially preferred embodiment the swirl generator is attached to the outer body. The advantage of the swirl generator being attached to the outer body is that it results in a better separation (as liquid that makes contact with the swirl generator is guided along the swirl generator surface towards the outer body, thus avoiding re-entrainment or atomisation of liquid, which would reduce separation performance); also, this provides a more sturdy design (no loose rotating element) resulting in less maintenance.

In some embodiments, the swirl generator may also be attached to the inner body; in the latter case, the swirl generator also serves to rigidly connect the inner body and the outer body, which then co-rotate during use.

In another preferred embodiment, the swirl generator is arranged upstream of the annular flow path between the inner body and the outer body. Preferably, the swirl generator is attached to (an inner wall of) the housing.

It goes without saying that two or more swirl generators may be present. Hence, it may be the case that a first swirl generator is arranged in the annular flow path between the inner body and the outer body and a second swirl generator upstream of the annular flow path.

According to the present invention, the apparatus further comprises a swirl reducer for reducing a swirling flow in the annular flow path between the inner body and the outer body, preferably at a point where removal of the contaminant has been achieved. The purpose of the swirl reducer is to convert kinetic energy of the swirling flow into pressure, thus reducing pressure loss between the inlet (for the contaminated stream) and the first outlet (for the contaminant-depleted stream) of the housing. The person skilled in the art will readily understand that this swirl reducer may have various shapes. As an example, the swirl reducer may comprise one or more guide vanes, wing-like structures, curvilinear structures (e.g. having a helical surface), etc. The swirl reducer may be attached to the inner body, the outer body or both, or to (an inner wall of) the housing, just downstream of the annular flow path.

According to one embodiment, the swirl reducer is located in the annular flow path between the inner body and the outer body, downstream of the protrusion. Preferably, for this embodiment, the swirl reducer is attached to the inner body.

According to a further embodiment, the swirl reducer is located downstream of the annular flow path between the inner body and the outer body. Preferably, for this embodiment, the swirl reducer is attached to (an inner wall of) the housing.

It goes without saying that two or more swirl reducers may be present. Hence, it may be the case that a first swirl reducer is arranged in the annular flow path between the inner body and the outer body, downstream of the protrusion, and a second swirl reducer downstream of the annular flow path.

As mentioned above, the outer body comprises a chamber for receiving a contaminant, the chamber being fluidly connected to the annular flow path between the inner body and the outer body. To this end, the outer body typically comprises openings between the chamber of the outer body and the annular flow path between the inner body and the outer body. This allows the contaminant (which has a higher mass density) to enter the chamber in the outer body, with only a small or negligible amount of a lighter phase. It goes without saying that these openings may have many shapes and sizes such as slits or perforations. These openings may be combined with surface topologies on the wall of the outer body facing the annular flow path, thereby allowing the (more dense) contaminant to flow with less disturbance by the main flow through the annular flow path, and hence improving the removal of the contaminant. Preferably, the openings of the outer body are located near the protrusion of the inner body (and hence at a point where the inner facing wall of the outer body is farthest removed from the rotation axis), more specifically at and downstream of the swirl generator and upstream of the swirl reducer.

According to an especially preferred embodiment of the apparatus according to the present invention, the chamber of the outer body has an outlet which is fluidly connected with the second outlet of the housing. The outlet of the chamber and the second outlet of the housing may have various forms and shapes; preferably they form together a swivel arrangement.

Further it is preferred that the inlet and the first outlet of the housing are coaxial. In this way, the apparatus can be easily built-in in existing pipelines or process equipment.

Also, it is preferred that the inner body has at least two protrusions. Preferably, the two or more protrusions are axisymmetric with respect to the rotation axis.

In a further aspect, the present invention provides a method for removing a contaminant from a contaminated stream, in particular a liquid contaminant from a gaseous contaminated stream, using the apparatus according to the present invention, the method at least comprising:

(a) providing a contaminated stream to be separated;

(b) feeding the contaminated stream through the first inlet of the housing;

(c) inducing the contaminated stream to swirl whilst flowing through the annular flow path between the inner body and the outer body;

(d) allowing contaminant to flow from the annular flow path into the chamber in the outer body;

(e) removing a contaminant-enriched stream from the apparatus via the second outlet (preferably via the outlet of the chamber);

(f) removing a contaminated-depleted stream from the apparatus via the first outlet;

wherein the swirling flow in the annular flow path between the inner body and the outer body is reduced downstream of the protrusion. Hence, pressure of the contaminated-depleted stream is recovered by reducing the swirl component of velocity with one or more swirl reducers.

Hereinafter the invention will be further illustrated by the following non-limiting drawings. Herein shows:

Fig. 1 a schematic cross-sectional side view of an apparatus in accordance with the present invention, with cross-sectional views along lines B-B′ in Fig. 1A and C-C′ in Fig. 1B;

Fig. 2 a schematic cross-sectional side view of the inner body 3 and outer body 4 of Fig. 1, with cross-sectional views along lines D-D′ in Fig. 2A and E-E′ in Fig. 2B;

Fig. 3 a perspective view of the inner body 3 as used in Figs. 1 and 2;

Fig. 4 a perspective view of the apparatus of Fig. 1; and

Fig. 5 a schematic cross-sectional side view of an alternative apparatus in accordance with the present invention.

For the purpose of this description, same reference numbers refer to same or similar components.

Fig. 1 shows a simplified apparatus 1 in accordance with the present invention for removing a contaminant from a contaminated stream 10. In the embodiment of Fig. 1, the contaminated stream 10 is a multiphase stream containing gas and liquid, the liquid being the contaminant.

The apparatus 1 comprises a stationary housing 2, an elongated inner body 3 arranged in the housing 2, an outer body 4 arranged in the housing 2 and around the inner body 3, a first swirl generator 6, a second swirl generator 13, a first swirl reducer 8 and a second swirl reducer 9. In the embodiment of Figure 1, two swirl generators and two swirl reducers are shown; however, the person skilled in the art will understand that one or more than two swirl generators may be present and that one or more than two swirl reducers may be present. Further, for the sake of simplicity, no driver has been shown that ensures rotation of the inner body 3 and outer body 4 around the axis A-A′ (although, of course, rotation may also be achieved passively, using the flow of the contaminated stream 10). Furthermore, also for the sake of simplicity, no bearing arrangement has been shown; however, the person skilled in the art will understand that (e.g. radial) bearings can be included in the apparatus 1 to allow rotational motion of outer body 4 with minimum or no vibrations.

The stationary housing 2 has an inlet 21 for the multiphase contaminated stream 10, a first outlet 22 for a contaminant-depleted stream 20 (in the embodiment of Fig. 1 a gas stream) and a second outlet 23 for a contaminant-enriched stream 30 (in the embodiment of Fig. 1 a liquid stream). In the embodiment of Fig. 1 the inlet 21 and first outlet 22 of the housing 2 are coaxial.

In the embodiment of Fig. 1 the inner body 3 and the outer body 4 extend along a common rotation axis A-A′, are attached to each other via first swirl generator 6 and first swirl reducer 8; as a result, the inner body 3, the outer body 4, the first swirl generator 6 and the first swirl reducer 8 can co-rotate during use in the housing 2 as one single assembly around this rotation axis A-A′. The inner body 3 and the outer body 4 define an annular flow path 5 between them. The inner body 3 has a protrusion 3A facing towards the outer body 4 thereby locally (near the protrusion 3A) narrowing the annular flow path 5 (see in this respect also cross-section D-D′ in Fig. 2A). The protrusion 3A is axisymmetric with respect to the axis A-A′.

The outer body 4 comprises a chamber 7 for receiving a contaminant (in the embodiment of Fig. 1 a liquid contaminant). In the embodiment of Fig. 1, the chamber 7 is the hollow core of the outer body 4. The chamber 7 is fluidly connected to the annular flow path 5 between the inner body 3 and the outer body 4. To this end, the outer body 4 comprises openings 11 in the wall thereof, i.e. between the chamber 7 of the outer body 4 and the annular flow path 5 between the inner body 3 and the outer body 4. These openings 11 in the wall of the outer body 4 are located near the protrusion 3A of the inner body 3, downstream of the (leading edge of the) first swirl generator 6 and upstream of the swirl reducers 8 and 9. The chamber 7 of the outer body 4 has an outlet 24 which is fluidly connected with the second outlet 23 of the housing 2. In the embodiment of Fig. 1 the outlet 24 of the chamber 7 and the second outlet 23 of the housing 2 are in the form of a production swivel arrangement. Preferably, and as shown in Fig. 1, the outlet 24 is placed at such a location that during use the liquid contaminant flows to the outlet 24 as a result of centrifugal action; to this end the outlet 24 is preferably located at a point of the chamber 7 that is farthest away from the axis A-A'. The chamber 7 may contain further openings 12, which open into a point downstream of the swirl reducer 8 to allow gas entrained with the liquid contaminant flown from the annular flow path 5 into the chamber 7 of the outer body 4 to leave the chamber 7 via these openings 12. The location of the openings 12 is such that the gas stream exiting the chamber 7 is depleted of liquid contaminant, due to the centrifugal motion in the chamber 7. In the embodiment of Fig. 1 further openings 14 are shown, which open at a point just downstream of the second swirl generator 13.

The first swirl generator 6 is included for inducing a swirling flow in the annular flow path 5 between the inner body 3 and the outer body 4. Although the first swirl generator 6 can be placed in many different places, the first swirl generator 6 is preferably arranged in the annular flow path 5 between the inner body 3 and the outer body 4, more preferably upstream of the protrusion 3A of the inner body 3. In the embodiment of Fig. 1 the first swirl generator 6 is attached to both the inner body 3 and the outer body 4 and in the form of aerodynamically shaped guide vanes. In the embodiment of Figure 1 also a second swirl generator 13 is shown, which is located upstream of the annular flow path 5. The second swirl generator 13 is attached to an inner wall of the housing 2 and hence does not rotate during use of the apparatus 1.

In the embodiment of Fig. 1 the apparatus 1 comprises a first swirl reducer 8 and a second swirl reducer 9 for reducing the generated swirling flow in the annular flow path 5. The first and second swirl reducers 8 and 9 may be located outside the housing 2 (i.e. further downstream), but in the embodiment of Fig. 1, both swirl reducers 8 and 9 are located within the housing 2. The first swirl reducer 8 is located in the annular flow path 5 between the inner body 3 and the outer body 4 (and attached to both the inner body 3 and outer body 4 and hence rotating during use), downstream of the protrusion 3A, whilst the second swirl reducer 9 is stationary placed just outside the annular flow path 5 and attached to an inner wall of the housing 2 (and hence not rotating during use).

In the embodiment of Fig. 1 a primary separation takes place by swirling motion in the annular flow path 5, whilst a secondary separation takes place by centrifugal motion in the chamber 7.

During use of the apparatus 1, a multiphase contaminated stream 10 to be separated is provided. The contaminated stream 10 (containing gas and a liquid contaminant) is fed through the first inlet 21 of the housing 2 and induced to swirl (by swirl generators 6 and 13) whilst flowing through the annular flow path 5 between the inner body 3 and the outer body 4. By means of the swirl a tangential velocity is induced, which causes a centrifugal force on the multiphase stream. The liquid contaminant in the multiphase stream tends to move radially outward and away from the inner body 3 and collects as a film at the surface of the rotating outer body 4, which surface is faced to the annular flow path 5. The liquid contaminant in the multiphase contaminated stream 10 is then allowed to flow (by the action of centrifugal forces) from the annular flow path 5 (via openings 11) into the chamber 7 in the outer body 4. Centrifugal forces direct the liquid contaminant to the outlet 24 (being preferably located at a point of the chamber 7 that is farthest away from the axis A-A’). A contaminant-enriched stream 30 is removed from the apparatus 1 via the (outlet 24 of the chamber 7 and the) second outlet 23 of the housing 2. Centrifugal forces will direct gas that enters chamber 7 via openings 12 (and 14) back into the annular flow path 5; this reduces the gas content in the contaminant-enriched stream 30. A contaminated-depleted stream is passed via the swirl reducers 8 and 9 and removed from the apparatus 1 via the first outlet 22 as stream 20 for further processing, if desired.

The rotation of the outer body 4 (and in case of the embodiment of Fig. 1 the inner body 3 as well) around the axis A-A’ may result in one or more of the following advantages:

(a) the centrifugal force stabilizes the liquid film (in case a liquid contaminant is being separated) collected at the surface of the outer body 4 in the annular flow path 5, thereby minimizing irregularities or waves in the gas/liquid interface. This reduces frictional pressure drops associated with rough liquid films. Also, the initiation of liquid re-entrainment (that starts with film roughness) is reduced.

(b) the difference in tangential velocity between the gas flow through the annular flow path 5 and the liquid film is considerably smaller than in the case of a non-rotating outer body 4 at the same tangential velocity, thus reducing turbulence and the associated detrimental effects thereof.

(c) the liquid film collected at the surface of the outer body 4 is pushed radially outwards by centrifugal forces, supporting the liquid flow through the openings 11.

Further, the relative configuration of the inner body 3 (with protrusion 3A) and outer body 4 drives the liquid film in the direction that is opposite to the axial gas flow, as the centrifugal force has a non-zero axial component, and towards the point in the annular flow path 5 that is farthest away from the rotation axis A-A′ (i.e. near openings 11 in the outer body 4 facing the protrusion 3A of the inner body 3). Also, the tangential velocity of the swirling flow in the annular flow path 5 increases in magnitude between the protrusion 3A and the first swirl reducer 8, due to conservation of angular momentum; this effect increases the centrifugal forces and improves the separation of gas and liquid.

If desired, (gaseous, liquid and/or solid) additives may be added to the contaminated stream 10 to be separated at any point, e.g. in order to change temperature, initiate a reaction, etc. Further, the apparatus 1 may be placed vertically, horizontally or under any desired angle.

The axial velocity in the annular flow path 5 during use is preferably from 2 to 50 m/s. The tangential velocity in the annular flow path 5 is preferably 2 to 10 times higher than the axial velocity. The total velocity in the annular flow path 5 is preferably from 5 to 250 m/s. The outer body 4 typically rotates around the rotation axis A-A′ with a speed in the range of from 100 to 15,000 rpm.

The apparatus 1 can process a wide range of contaminant streams and operate at various pressures and temperatures, as long as there is a difference in mass density between a first and a second component in the contaminated stream. Hence, the apparatus 1 according to the present invention is not only suitable for gas/liquid separation, but also for e.g. liquid/liquid separation such as in the separation of oil/water.

Fig. 2 schematically shows a schematic cross-sectional side view of the inner body 3 and outer body 4 of Fig. 1, with cross-sectional views along lines D-D′ in Fig. 2A and E-E′ in Fig. 2B. As can be seen at cross-section D-D′ in Fig. 2A, the protrusion 3A of the inner body 3 narrows the annular flow path 5 between the inner body 3 and the outer body 4 locally.

Figure 3 shows a perspective view of the inner body 3 as used in Figs. 1 and 2 (wherein the outer body 4 has been omitted for the sake of clarity), with the first swirl generator 6 and the first swirl reducer 8 attached thereto.

Fig. 4 shows a perspective view of the apparatus 1 of Fig. 1.

Fig. 5 shows a schematic cross-sectional side view of an alternative apparatus 1 in accordance with the present invention. As can be seen in Figure 5, the inner body 3 contains a first protrusion 3A, a second protrusion 3B and a throat portion 3C in between them. Both protrusions 3A and 3B are axisymmetric with respect to the rotation axis A–A'. The embodiment of Fig. 5 achieves a higher pressure recovery efficiency by reducing the tangential velocity in the diverging section of the annular flow path 5 between the throat 3C and the second protrusion 3B; hence the swirl reducers 8 and 9 can operate at smaller velocity. A further advantage is that the axial force on the rotating assembly (containing the inner body 3, the outer body 4, the first swirl generator 6 and the first swirl reducer 8) due to pressure can be balanced: a pressure in the first outlet 22 that is lower than the pressure in the inlet 21 is compensated by increasing the surface area of the rotating assembly at the axial position of protrusion 3B; this reduces or avoids the need for an axial thrust bearing arrangement.

The person skilled in the art will readily understand that many modifications may be made without departing from the scope of the invention. Further, the person skilled in the art will readily understand that, while the present invention in some instances may have been illustrated making reference to a specific combination of features and measures, many of those features and measures are functionally independent from other features and measures given in the respective embodiment(s) such that they can be equally or similarly applied independently in other embodiments.

C L A I M S

1. An apparatus (1) for removing a contaminant from a contaminated stream (10), the apparatus (1) at least comprising:
- a housing (2) having an inlet (21) for a contaminated stream (10), a first outlet (22) for a contaminant-depleted stream (20) and a second outlet (23) for a contaminant-enriched stream (30);
- an inner body (3) arranged in the housing (2);
- an outer body (4) arranged in the housing (2) and around the inner body (3), which outer body (3) is mounted for rotation in the housing (2) around a rotation axis (A-A'), wherein the inner body (3) and the outer body (4) define an annular flow path (5) between them;
- a swirl generator (6,13) for inducing a swirling flow in the annular flow path (5) between the inner body (3) and the outer body (4);
- a swirl reducer (8,9) for reducing a swirling flow in the annular flow path (5) between the inner body (3) and the outer body (4);

wherein the inner body (3) has a protrusion (3A) facing towards the outer body (4), and

wherein the outer body (4) comprises a chamber (7) for receiving a contaminant, the chamber (7) being fluidly connected to the annular flow path (5) between the inner body (3) and the outer body (4).

2. The apparatus (1) according to claim 1, wherein the inner body (3) can rotate around the rotation axis (A-A') of the outer body (4).

3. The apparatus (1) according to claim 1 or 2, wherein the inner body (3) and the outer body (4) are attached to each other.

4. The apparatus (1) according to any one of claims 1-3, wherein a swirl generator (6) is arranged in the annular flow path (5) between the inner body (3) and the outer body (4), preferably upstream of the protrusion (3A) of the inner body (3).

5. The apparatus (1) according to claim 4, wherein the swirl generator (6) is attached to the outer body (4).

6. The apparatus (1) according to any one of claims 1-5, wherein a swirl generator (13) is arranged upstream of the annular flow path (5) between the inner body (3) and the outer body (4).

7. The apparatus (1) according to claim 6, wherein the swirl generator (13) is attached to the housing (2).

8. The apparatus (1) according to any one of claims 1-7, wherein the swirl reducer (8) is located in the annular flow path (5) between the inner body (3) and the outer body (4), downstream of the protrusion (3A).

9. The apparatus (1) according to claim 8, wherein the swirl reducer is attached to the inner body (3).

10. The apparatus (1) according to any one of claims 1-9, wherein the swirl reducer (9) is located downstream of the annular flow path (5) between the inner body (3) and the outer body (4).

11. The apparatus (1) according to claim 10, wherein the swirl reducer (9) is attached to the housing (2).

12. The apparatus (1) according to any one of claims 1-11, wherein the outer body (4) comprises openings (11) between the chamber (7) of the outer body (4) and the annular flow path (5) between the inner body (3) and the outer body (4).

13. The apparatus according to claim 12, wherein the openings (11) of the outer body (4) are located near the protrusion (3A) of the inner body (3).

14. The apparatus (1) according to any one of the claims 1-13, wherein the chamber (7) of the outer body (4) has an outlet (24) which is fluidly connected with the second outlet (23) of the housing (2).

15. A method for removing a contaminant from a contaminated stream (10), in particular a liquid contaminant from a gaseous contaminated stream, using the apparatus (1) according to any one of claims 1-14, the method at least comprising:

(a) providing a contaminated stream (10) to be separated;

(b) feeding the contaminated stream (10) through the first inlet (21) of the housing (2);

(c) inducing the contaminated stream (10) to swirl whilst flowing through the annular flow path (5) between the inner body (3) and the outer body (4);

(d) allowing contaminant to flow from the annular flow path (5) into the chamber (7) in the outer body (4);

(e) removing a contaminant-enriched stream (30) from the apparatus (1) via the second outlet (23);

(f) removing a contaminated-depleted stream (20) from the apparatus (1) via the first outlet (22);

wherein the swirling flow in the annular flow path (5) between the inner body (3) and the outer body (4) is reduced downstream of the protrusion (3A).

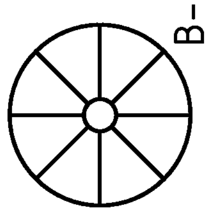

FIG. 1A

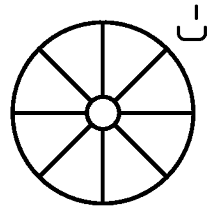

FIG. 1B

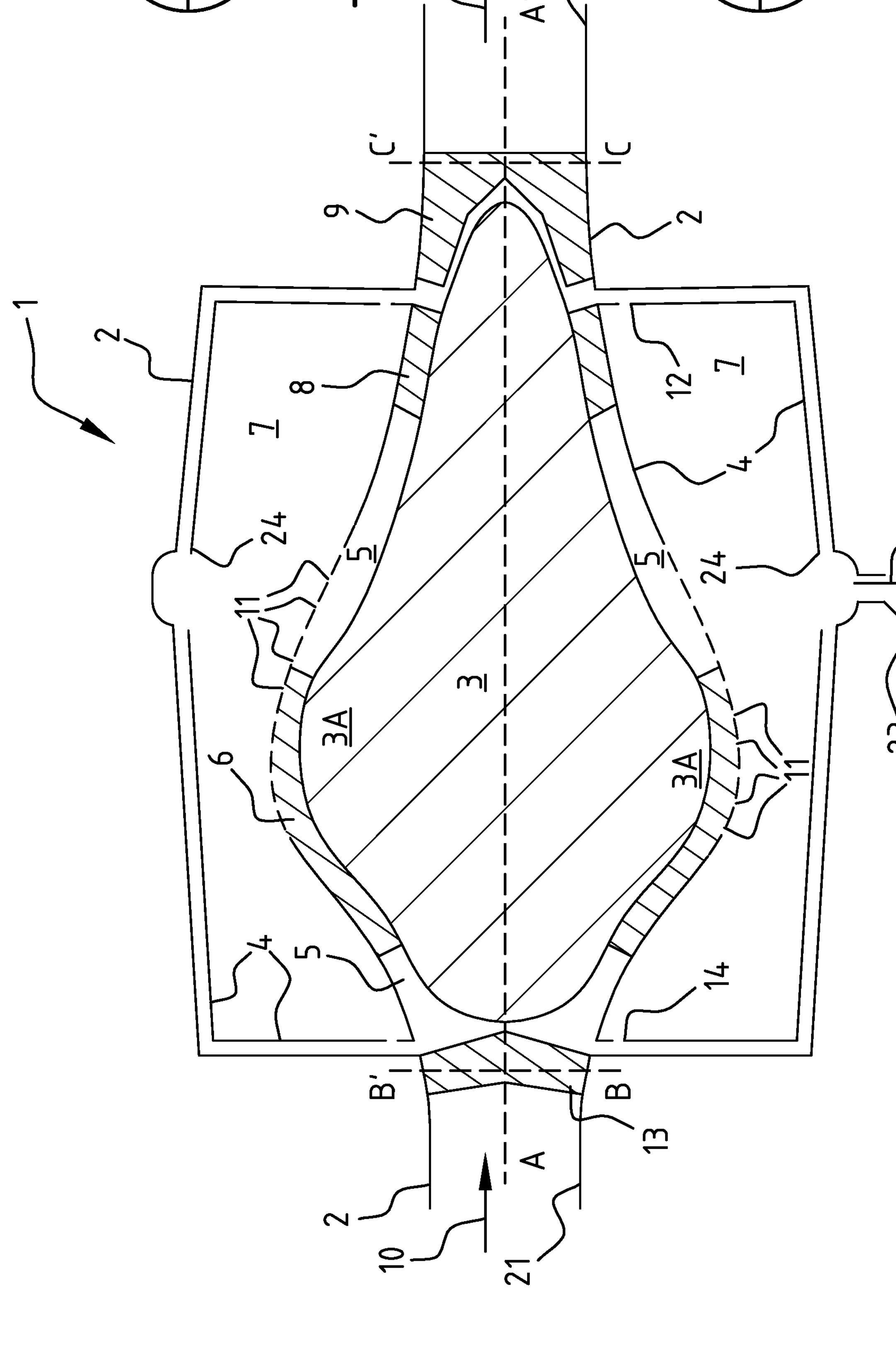

FIG. 1

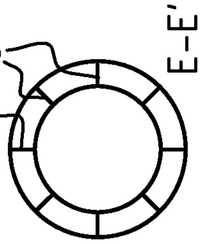

FIG. 2B

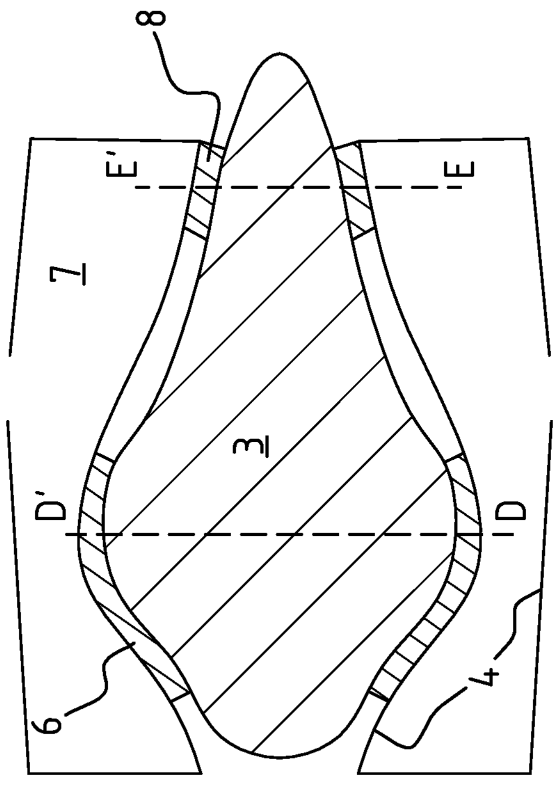

FIG. 2

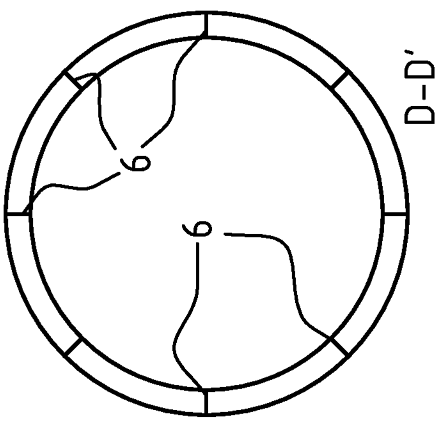

FIG. 2A

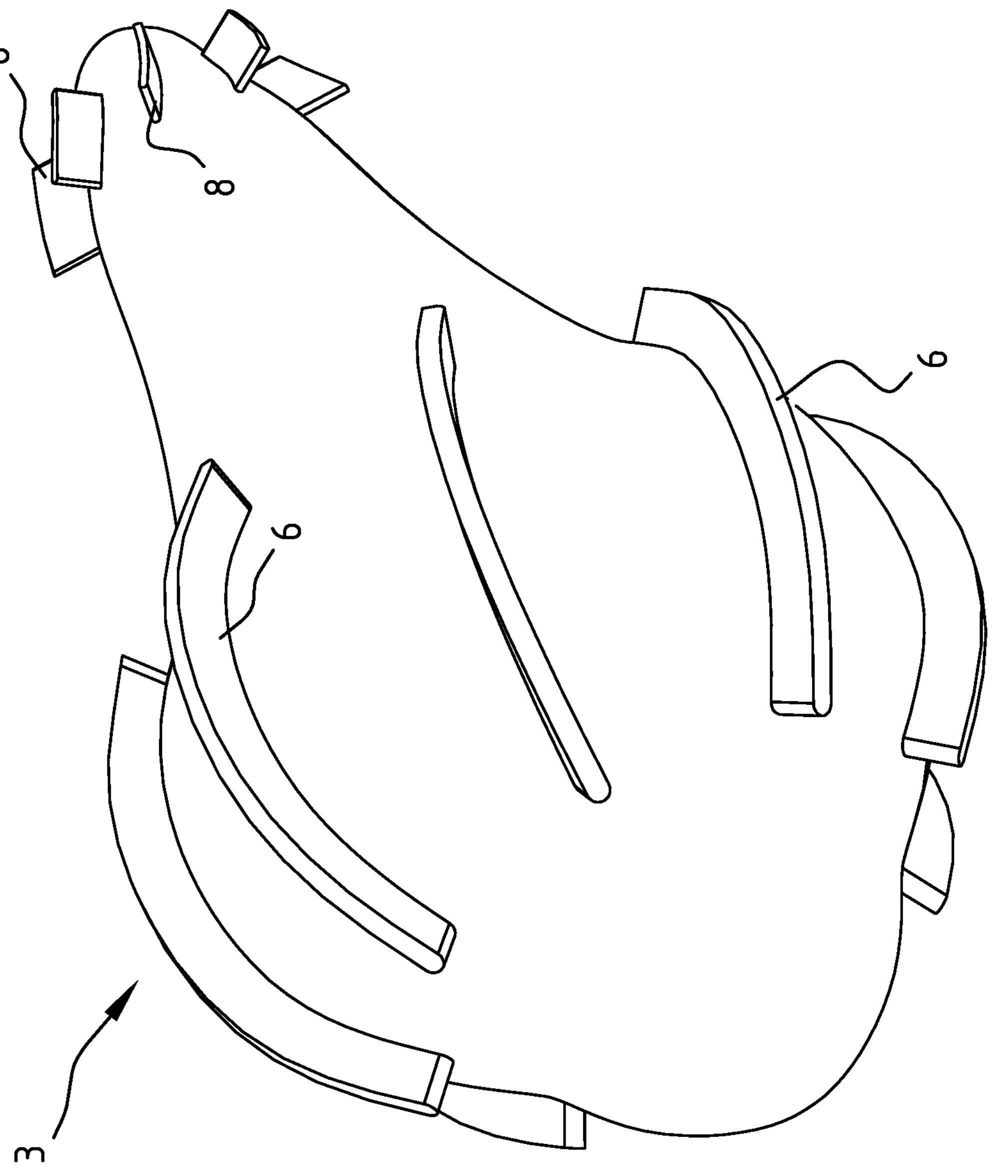

FIG. 3

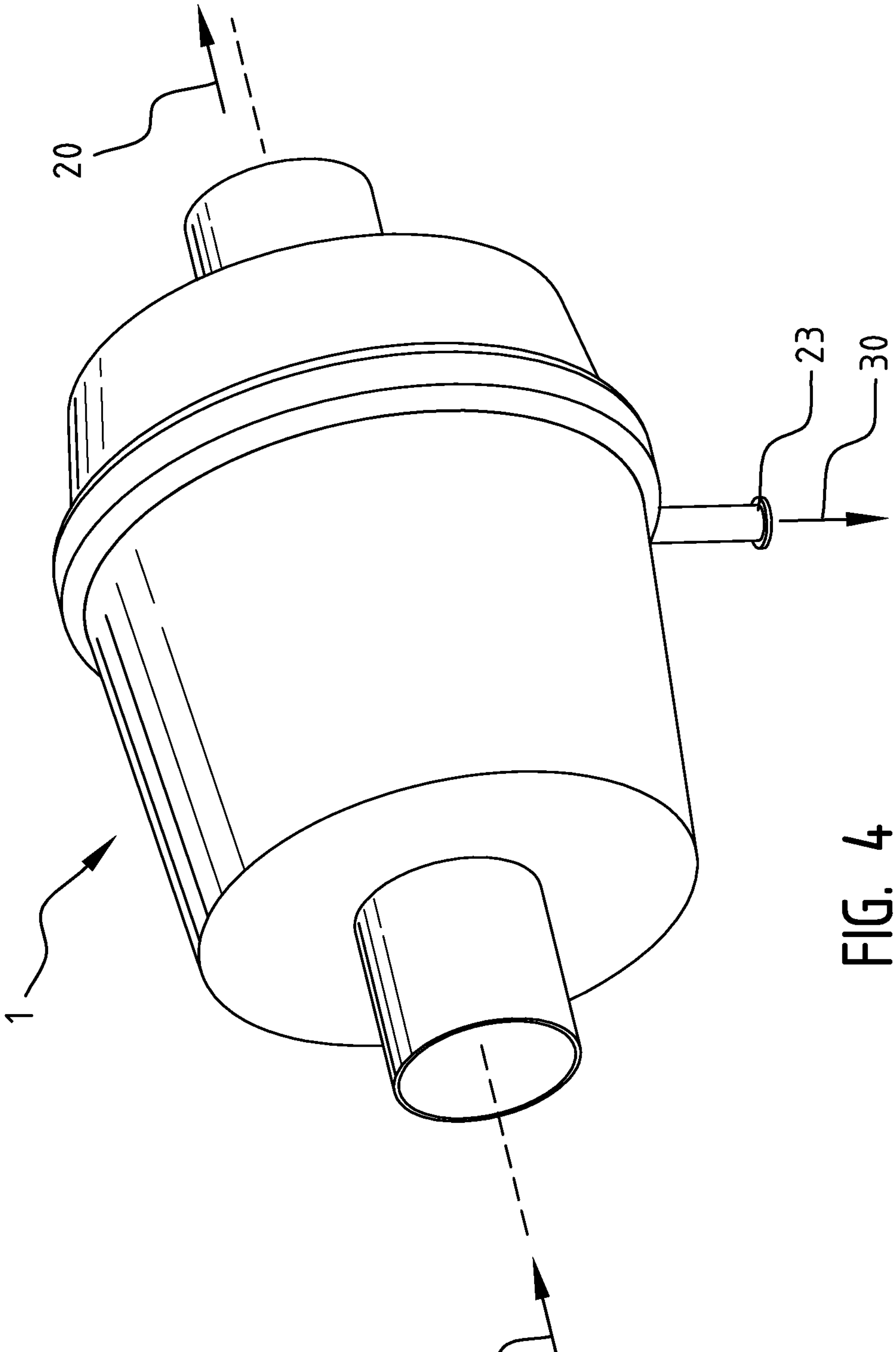

FIG. 4

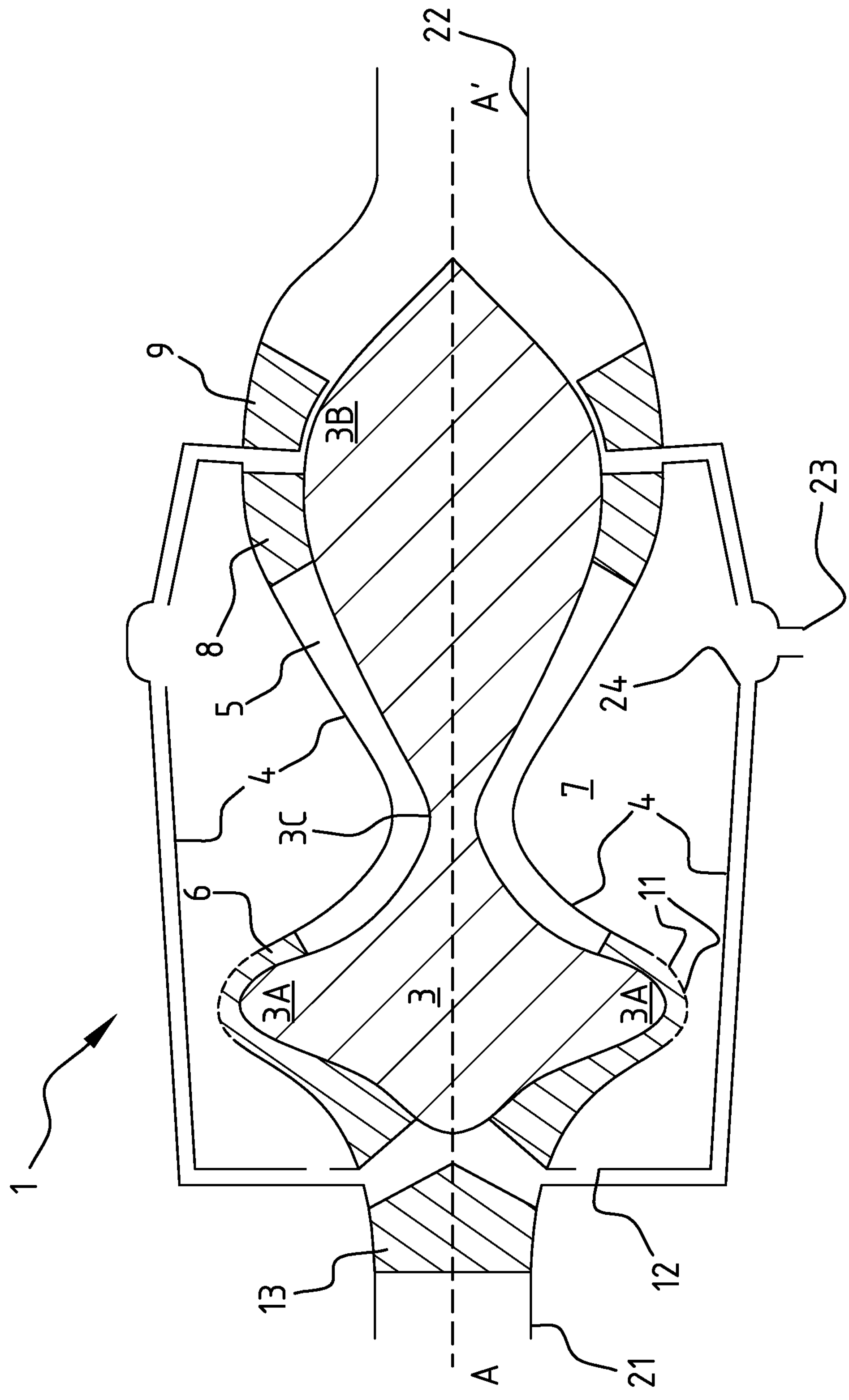

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/062478

A. CLASSIFICATION OF SUBJECT MATTER
INV. B01D53/24 B01D45/14 B04B1/04 B04B5/08
ADD.

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)
B01D B04B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 95/24959 A1 (LUNGU TURODEL [RO]) 21 September 1995 (1995-09-21) pages 4,5; figure	1-12,14, 15
X	GB 237 617 A (STANISLAW PRUS SZCZEPANOWSKI) 22 October 1926 (1926-10-22) page 3, line 128 - page 4, line 79; figure 2	1-5,8-15
X	US 5 387 342 A (ROGERS ERNEST E [US] ET AL) 7 February 1995 (1995-02-07) column 15, line 41 - column 17, line 59; figure 9	1-3,5,6, 13-15
A	EP 1 600 215 A1 (FLASH TECHNOLOGIES N V [AN]; FMC TECHNOLOGIES C V [US]) 30 November 2005 (2005-11-30) paragraphs [0032], [0033]; figures	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 September 2013	13/09/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Persichini, Carlo

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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