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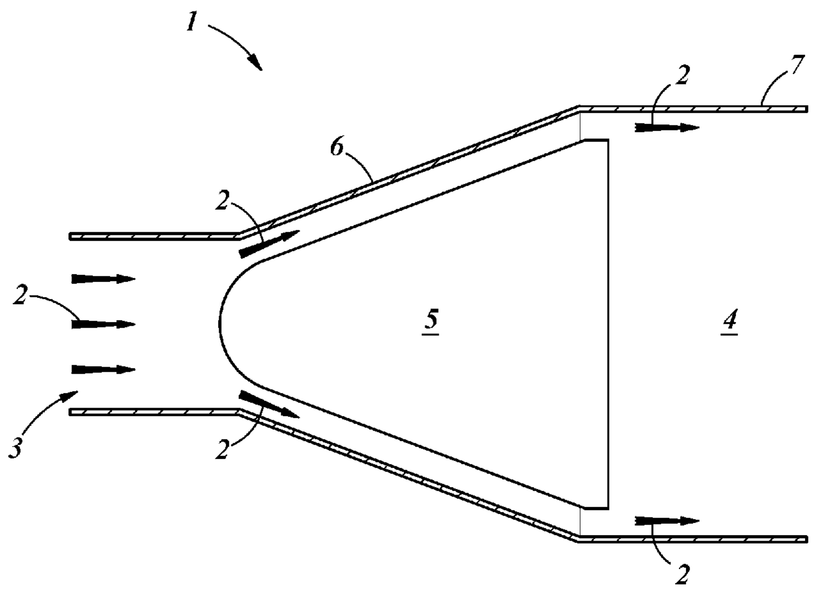

FIGURE 1

(57) **Abstract:** This invention relates to a scrubber and more particularly, but not exclusively, to a scrubber for scrubbing a gas or air stream. The scrubber includes a scrubber body with a flow path between an inlet and an outlet of the body. At least a part of the body is frusto conically shaped so that the flow path therein is also frusto conical. The frusto conical part of the body has at least part of an insert supported, with support means, therein.

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A SCRUBBER

FIELD OF THE INVENTION

This invention relates to a scrubber and more particularly, but not exclusively, to a scrubber for scrubbing a gas or air stream.

BACKGROUND TO THE INVENTION

Cyclonic spray scrubbers are well-known and widely used, especially in air pollution control technology. The features of both a dry cyclone and a wet cyclone can be used to remove particles or pollutants from gas or air streams.

In general, an inlet gas enters a cylindrical chamber tangentially, swirls through the chamber in a corkscrew motion, and exits. As the gas swirls around the chamber, centrifugal forces force heavier particles or pollutants to impact the wall of the chamber. In addition, and at the same time, in so-called wet scrubbers, liquid may be sprayed inside the chamber. This ensures that many, even relatively light pollutants or particles, are removed when they impact on, or coagulate with, liquid droplets. The wet pollutants or particles are forced onto the wall of the chamber and are washed down and out against the wall of the chamber.

Other types of scrubbers similarly include elongate cylindrical or tubular bodies with an impeller to force air therethrough. Mechanical filters, usually made of stainless steel, are located in the flow path defined by these cylinders or tubular bodies. The filters, once clogged, can be rinsed off for re-use. Impellers are located upstream or downstream of the filters.

Many such air scrubbers are mounted on continuous mining machines to, inter alia, improve visibility, but more importantly, guard against dust hazards whilst mining. These hazards include skin, eye and respiratory tract irritation. Prolonged exposure to dust, such as coal dust, can also lead to lung disease. Coal dust suspended in air is further also explosive.

An example of an air scrubber, using both a cyclone and a venturi, in series, is disclosed in United States patent number 5,472,645 in the name of Cyclone Technologies Inc., entitled "Cyclone vortex system and process". This patent discloses "... *a system and process for fuel or liquid preparation including a plurality of vortex stacks of sequential vortex elements operationally coupled with an integrated pre-manifold centrifuge type-cyclone scrubber. Each vortex stack comprises a base vortex element having a fuel-air mixture input followed by varying arrangements of air-accelerator vortex elements. An electronic fuel injection managed fuel-air mixture enters each base vortex element creating a vortical (spinning) column, which is enhanced and accelerated by transonic-sonic velocity air inflows in the accelerator vortex elements. Entrained fuel aerosol droplets are sheared into a viscous vapor phase, and then into a gas-phase state. The vortical column containing turbulently vaporized fuel and any residual aerosols in the air mixture is then passed through a venturi to the scrubber where the mixture is homogenized and any collected aerosols are returned as liquid and re-processed by the system. This allows only the vaporized, chemically stoichiometric (oxygen balanced) and combustion ready gas-phase fuel to exit the system.*".

OBJECT OF THE INVENTION

It is an object of this invention to provide a scrubber.

SUMMARY OF THE INVENTION

In accordance with this invention there is provided a scrubber comprising a scrubber body having a flow path between an inlet and an outlet of the body, at least a part of the body being frusto conical so that the flow path therein is frusto conical, the frusto conical part of the body having at least part of an insert supported, with support means, therein.

The insert is supported centrally with respect to the flow path with at least part of the insert inside part of the frusto conical part of the body to, in cross-section, define an annular flow path between an inner surface of the conical part of the body and an outer surface of the insert.

The body defines an inlet flow path between its inlet and an annular flow path inlet of the annular flow path and an outlet flow path between an annular flow path outlet of the annular flow path and the outlet.

A further feature of the invention provides for the body to be tubular having a frusto conical mid-section and co-axial right-circular inlet and outlet sections which define the inlet and outlet flow paths.

The inlet flow path and the outlet flow path are of constant inner diameter with the inner diameter of the inlet flow path smaller than the inner diameter of the outlet flow path, to accommodate and align with the frusto conical part therebetween.

A yet further feature of the invention provides for the inner diameter of the inlet flow path to be equal to the inner diameter of the inlet of the annular flow path and for the inner diameter of the outlet flow path to be equal to the inner diameter of the outlet of the annular flow path.

At least part of the part of the insert inside the frusto conical part of the body is complementary frusto conically shaped to the frusto conical part of the body.

The scrubber includes rotation means.

There is provided for the rotation means to be an impeller and for the impeller to be a driven impeller, driven by an energy source. The impeller is located in or at the inlet. Alternatively, or in addition, the rotation means is cyclone means in the form of a number of deflectors fins supported in the flow path to deflect air moving through the flow path. Preferably, the fins are supported in the annular flow path.

Further features of the invention provide for the fins to be secured between an outer surface of the insert and an inner surface of the frusto conical part; alternatively, for the fins to be secured either to only the outer surface of the insert or only the inner surface of the frusto conical part.

There is provided for the position of the insert to be adjustable, co-axially, inside the flow path.

The insert is selectively securable at any point between an open position, in which the complementary shaped part thereof is inside the conical part of the body and a closed position in which a larger section of its complementary shaped part is inside the conical part of the body.

A still further feature of the invention provides for spray means to be located in the flow path.

As is known in the art, particles in the air stream in the flow path collide with and are captured by the mist and is thus removed from an air stream.

The mist sprayers used spaced about an inner circumference of the body, axially upstream of the inlet or impeller and downstream of the outlet of the annular flow path. Alternatively, or in addition, the sprayers are spaced about a circumference of the insert, preferably, on its complementary shaped section.

The sprayers may be sunk into the respective surfaces in which they are mounted so that outlet openings thereof are substantially flush with such surfaces to limit interference with the flow in the flow path.

There is thus provided for the flow path to have a constant diameter for an inlet section thereof and for the effective cross-sectional area of the inlet section to be larger than the effective cross-sectional area of the inlet to the annular flow path, for the effective cross sectional area of the outlet of the flow path to be larger than that of the inlet of the annular flow path and to be larger or smaller than the effective cross-sectional area of the inlet section of the flow path.

A still further feature provides for the flow path to have an outlet section with a larger effective cross sectional area than the outlet of the annular flow path.

The invention extends to a scrubbing method including the steps of:

- providing a conically shaped flow path in a body between an inlet and an outlet;
- locating at least part of an insert centrally in the conically shaped flow path to form, in cross-section, an annular flow path between an outer surface of the insert an inner surface of the conically shaped part of the body; and
- creating rotational flow in the annular flow path with rotation means.

The annular flow path increases in effective cross-sectional surface area from the inlet to the outlet.

The step of creating rotational flow includes creating rotational air flow spiraling through the annular flow path from the inlet to the outlet.

There is further provided for the step of placing the at least part of the insert in the conically shaped part includes adjusting the axial position of the insert inside the conically shaped part so that a larger or smaller section of the insert locates in the conically shaped part and securing the insert in position, once adjusted.

The method includes the step of introducing liquid mist or spray into the annular flow path or at or in front of the inlet.

An outer surface of the insert is shaped complementary to the conical part, but smaller in diameter than the conical part.

These and other features of invention are described in more detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention are described below, by way of example only, and with reference to the drawings in which:

Figure 1 shows a schematic cross-sectional side view of a scrubber for explaining the principle of operation of the invention;

Figure 2 shows a side view of a scrubber of the type using the principle depicted in the schematic of figure 1;

Figure 3 shows a front end perspective view of the scrubber of figure 2;

Figure 4 shows a rear end perspective view of the scrubber of figures 2 and 3;

Figure 5 shows a part cross-sectional schematic side view of the scrubber of figures 2 to 4. Outer cylindrical walls of the scrubber are shown in cross-section with a plug and fins shown in side view only and parts of impeller fins shown in side view;

Figure 6 shows a cross-section schematic side view of a forward and central part of a second embodiment of a scrubber with a movable cone in an open position;

Figure 7 shows the same view as figure 6 but with the movable cone in a closed position;

Figure 8 shows a schematic view of cross-sections of the flow path at different positions along the length of a scrubber in accordance with the invention; and

Figure 9 shows a schematic cross-section of a part of a scrubber body having overlapping ends to form a slot.

DETAILED DESCRIPTION OF THE DRAWINGS

With reference to the drawings, in which like features are indicated by like numerals, a scrubber is generally indicated by reference numeral 1.

The scrubber 1 includes an elongate cylindrical scrubber body having a flow path 2 between an inlet 3 and an outlet 4 thereof. The scrubber body 1 is generally cylindrical with a smaller diameter inlet or first section 1a and larger diameter outlet or second section 7. A frusto conical section 6 extends co-axially between the inlet and outlet sections and is integral therewith.

At least part of the flow path includes an annular or ring shaped section, when viewed in transverse cross-section. Figures 8b and 8c depict this. This annular section is defined between an inner circumferential surface of the outer cylindrical wall sections 1a, 6 and/or 7 and an outer surface of an inner co-axial smaller diameter insert or plug 5.

With reference to the scrubber shown in figures 1 to 5, cyclone means 9, in the form of fins, for inducing, assisting or increasing spiral or cyclonic flow of air being forced through the flow path, are located in the annular flow path, preferably in the frusto conical section thereof.

The annular flow path, at its inlet end, in this embodiment, is in flow communication with a flow path section having a larger cross sectional area.

The flow path 2, at its inlet end 3, is defined by a right circular cylinder from where it leads into the frusto conical section 6. The flow path cross-sectional inlet surface area defined by section 1a is shown, schematically, in figure 8a. From approximately the end of section 1a, the flow path effective cross-sectional surface area is reduced by the plug 5 as is shown in figure 8b. The flow path effective cross-sectional area then increases along section 6 until it reaches the start of section 7, where it has a larger effective surface area than at the upstream end or start of section 6. The flow path surface are then remains constant for the rest of the length of the plug 5. At the plug downstream end, the effective flow path surface area increases abruptly, in the case of the scrubber of figures 1 to 5, and gradually, in the case of figures 6 and 7, until it matches the inside cross-sectional surface area of section 7. This is represented by figure 8 d.

Thus, from the inlet or upstream end of the annular flow path, its effective cross-sectional area increases, linearly, until it terminates in the second right circular cylinder section 7. From there it may either remain constant for a distance and then increase abruptly or gradually or from there it may immediately increase abruptly or gradually.

The plug 5 is elongate and right circular and locates coaxially within the second right circular cylinder 7. At its inlet end, the plug is conically shaped, preferably also frusto conically, to fit inside the frusto conical section 6 to form part of the annular flow path with its increasing effective surface area. A major part of the inlet end of the plug may be complementary frusto conically shaped i.e. having a similar angle to an angle defined by an inside surface of section 6. Alternatively, this inlet end of the plug may have an angle different to that defined by the inner surface of section 6, for a major part thereof.

An impeller 8 is located in the inlet 3, inside section 1a, to force air from the inlet 3 to the outlet 4. The impeller may be driven by an energy source such an electric motor.

Water mist or other liquid spray means (16 in figure 5 and 15 in figures 6 and 7) are spaced about the inner circumference of wall sections 1a and/or 6 to spray water in the form of a fine mist into the flow path. It will be appreciated by those skilled in the art that other liquid other than water can also be used, depending on the specific application of the scrubber.

The narrower section or throat of the flow path has an airgap of between 30 mm and 300 mm between an inner surface of the cylindrical wall sections 1a, 6 or 7 and an outer surface of the plug. This gap is adjustable as described below.

The frusto conical section of the path may vary from 200mm to 600mm (inner diameter) at its narrow or inlet end and from 250mm to 2000mm (inner diameter) at its wide or outlet end, with its outlet end always having a larger diameter than its inlet end.

The rotational velocity of the airstream in the cyclone may vary from 5 m/s to 35 m/s and linear velocity vector between 25 m/s to 160 m/s.

Particle sizes in the airstream may be between .1 micron to 1000 micron.

A gas to liquid ratio may be between 0.02 l/m^3 to 0.2 l/m^3.

In use, with the impeller in operation, air or gas is forced from the inlet 3 to the outlet 4. The inlet has a larger cross sectional area than the flow path defined between sections 6, 7 and the plug 5. The result is that the air speeds up in this part of the flow path so as to maintain constant pressure in accordance with flow dynamic principles. In addition, the fins 9 create or increase cyclonic or spiraling flow around the plug. The cyclonic flow around the plug further assists in maintaining, induces or increases the velocity of air flow as described in more detail below. This cyclonic flow creates centrifugal forces on particles in the air forcing the particles onto the inner surfaces of sections 1a, 6 and/or 7.

The introduction of water mist further assists in removing particles from the air. As is known in the art, particles in the air stream in the flow path collide with and are captured by the mist and is thus removed from the air stream. The mist sprayers or spray means used are commonly available in industry and have outlet openings anywhere along the length of the flow path and spaced circumferentially about the flow path on the inner surface cylindrical wall or on the outer surface of the plug. Preferably however, these are located as is shown by reference numerals 15 and 16. The sprayers may be sunk into the respective surfaces so that outlet openings thereof are substantially flush with such surface to limit interference with the flow in the flow path.

The fins 9 of the scrubber shown in figures 1 to 5 may be omitted provided the impeller remains upstream of the annular flow path. It is to be noted that the impeller and the fins together form rotation means but one of them used on its own might suffice to causes rotation or cyclonic movement of air through the flow path. The impeller induces spiraling or cyclonic movement of the air, thus, in many cases, obviating the need for the fins 9. In further alternative embodiments, the fins may be positioned as shown, upstream of the plug or downstream of the conical section (inlet end) of the plug. In these cases, the impeller will be in or at the outlet end of the scrubber to pull, instead of push, air through the scrubber.

The throat of the flow path is the narrowest section thereof. The size of the throat, being the shortest distance between the outside surface of the plug and the inner surface of the wall sections 1a, 6 or 7, is adjustable by adjusting the plug in an axial direction.

Figure 5 shows the plug supported with support means, centrally in the scrubber, by two diametrically opposed braces 14. The braces extend radially outwardly from an outer surface of the plug and terminate in free ends having holes there through. These holes in the braces are selectively aligned with one of a plurality of holes 13, spaced apart in flat bars 12. The flat bars 12 are secured, diametrically opposed to the inner surface of the wall section 7 of the scrubber. They extend coaxially, inside the scrubber, with respect to their elongate axes. A width of each flat bar extends radially inwardly. Bolts and nuts are used to secure the braces to the flat bars through their respective holes. In this manner, the plug 15 is adjustable in an axial direction with respect to the scrubber.

The plug 5 of the scrubber of figures 6 and 7 is similarly adjustable. In figure 6, the plug 5 is moved to its maximum open position, in the direction of arrow 10. Figure 7 shows the plug moved to its maximum closed position, in the direction of arrow 11. The plug of figures 6 and 7 is securable at any position between its open and closed positions.

The scrubbers described above rely on two known methods to achieve dust capture in a gas stream. The first is acceleration and particle capture by combining two dissimilar fluid velocities. The second is the use of centrifugal force in a cyclonic separator.

The gas or air stream laden with dust particles is forced from a larger diameter flow path into a smaller diameter flow path to accelerate the flow. In, or in close proximity to this accelerated flow region, a liquid mist is injected into the gas stream to capture dust particles.

The second method involves rotation. This further increases the velocity through the narrowed, annular section. As a result of rotation of the gas, the path that it has to follow is longer than travelling in a straight line. The gas thus moves even faster as a result of the increased path length.

Using the two methods together allows for better dust capture for a given cross-sectional reduction.

Typical test results achieved with a prototype unit are tabled below:

Dust level at 100 g/s

Test no	**Throat velocity**	**Water vol/min**	**Below 10 µm capture**	**Comments**
1	95 m/s	60 L/min	85%	Visible dust
2	100 m/s	60 L/min	90%	Visible dust
3	110 m/s	60 L/min	99%	No visible dust
4	115 m/s	60 L/min	99.5%	No visible dust
5	112 m/s	80 L/min	99.5%	Higher than 99.5%, no visible dust all entrained in water
6	95 m/s	120 L/min	95%	Low level visible dust
7	100 m/s	120 L/min	99%	No visible dust

All the tests tabled above were conducted by feeding coal dust at a rate of 100 g/s into the inlet of the scrubber. The plug was adjusted to achieve a throat velocity as indicated in each case above. The throat velocity is the air velocity as measured at the shortest distance between an outer surface of the plug and an inner surface of the wall 1a, 6 or 7, in other words, the narrowest section of the flow path. Water was introduced through spray nozzles spaced about the circumference of the inner surface of the walls as described above. Volumetric flow of the water was adjusted as shown in column 3 of the above table. The fourth column in the table above shows the percentage of dust, with a particle size smaller than 10 µm, captured during each test. The comments section, column 5 in the table above, is self-explanatory: air at the exit of the scrubber contained either some visible dust or no visible dust.

The wall of the rectifier may include a slot 17, as is known in the art, for draining coagulated or wet particles, under force of gravity and/or as a result of rotational movement, therefrom. The wall itself may have overlapping wall sections to define the slot 17. This configuration is shown in figure 9.

As is known in the art, the scrubber may have a flow rectifier as well as demisting vanes at, or in, its outlet end.

The scrubber described herein can be used in any application other than what is described or inferred herein. The scrubber can be used in mining, on or in conjunction with a continuous mining machine, in tunneling and other industrial applications where air needs to be scrubbed.

The invention is not limited to the precise details as described herein and many other embodiments are possible without departing from the scope of the invention. For example, the shape, length or angle of the frusto conical section and the complementary or unique shape of the plug can be changed to achieve different results. Different diameter plugs may also be used to achieve different flow path area reduction ratios.

CLAIMS

1. A scrubber comprising a scrubber body having a flow path between an inlet and an outlet of the body, at least a part of the body being frusto conical so that the flow path therein is frusto conical, the frusto conical part of the body having at least part of an insert supported, with support means, therein.
2. A scrubber as claimed in claim 1 in which the insert is supported centrally with respect to the flow path with at least part of the insert inside part of the frusto conical part of the body to, in cross-section, define an annular flow path between an inner surface of the conical part of the body and an outer surface of the insert.
3. A scrubber as claimed in any one of the preceding claims in which the body defines an inlet flow path between its inlet and an annular flow path inlet of the annular flow path and an outlet flow path between an annular flow path outlet of the annular flow path and the outlet.
4. A scrubber as claimed in claim 3 in which the body is tubular having the frusto conical part as its mid-section and co-axial right-circular inlet and outlet sections which define the inlet and outlet flow paths.
5. A scrubber as claimed in any one of claims 3 or 4 in which the inlet flow path and the outlet flow path are of constant inner diameter with the inner diameter of the inlet flow path smaller than the inner diameter of the outlet flow path, to accommodate, join and align with the frusto conical part therebetween.
6. A scrubber as claimed in any one of claims 3 to 5 in which the inner diameter of the inlet flow path is equal to the inner diameter of the inlet of the annular flow path and for the inner diameter of the outlet flow path to be equal to the inner diameter of the outlet of the annular flow path.
7. A scrubber as claimed in any one of the preceding claims in which at least part of the insert inside the frusto conical part of the body is complementary frusto conically shaped to the frusto conical part of the body.

8. A scrubber as claimed in any one of the preceding claims in which the scrubber includes rotation means.
9. A scrubber as claimed in claim 8 in which the rotation means includes an impeller and/or a cyclone means.
10. A scrubber as claimed in any one of claims 8 or 9 in which the rotation means includes an impeller and for the impeller to be a driven impeller, driven by an energy source.
11. A scrubber as claimed in claim 10 in which the impeller is located in or at the inlet.
12. A scrubber as claimed in claim 9 or 10, in which the rotation means includes cyclone means in the form of a number of deflectors supported in the flow path to deflect air moving through the flow path.
13. A scrubber as claimed in claim 12 in which the defectors are fins supported in the annular flow path.
14. A scrubber as claimed in claim 13 in which the fins are secured between an outer surface of the insert and an inner surface of the frusto conical part.
15. A scrubber as claimed in claim 13 in which the fins are secured either to only the outer surface of the insert or only the inner surface of the frusto conical part.
16. A scrubber as claimed in any one of the preceding claims in which the position of the insert is adjustable, co-axially, inside the flow path.
17. A scrubber as claimed in claim 16 in which the insert is selectively securable at any point between an open position, in which the complementary shaped part thereof is inside the conical part of the body and a closed position in which a larger section of its complementary shaped part is inside the conical part of the body.
18. A scrubber as claimed in any one of the preceding claims in which spray means are located in the flow path.

19. A scrubber as claimed in claim 18 in which the spray means are mist sprayers, spaced about an inner circumference of the body, axially upstream of the inlet or impeller and downstream of the outlet of the annular flow path.
20. A scrubber as claimed in claim 18 in which the spray means are mist sprayers, spaced about a circumference of the insert.
21. A scrubber as claimed in claim 20 in which the mist sprayers are spaced about a circumference of the insert on its complementary shaped section.
22. A scrubber as claimed in any one of claims 18 to 21 in which the sprayers are sunk into the respective surfaces in which they are mounted so that outlet openings thereof are substantially flush with such surfaces to limit interference with flow in the flow path.
23. A scrubber as claimed in any one of the preceding claims in which the flow path has a constant diameter for an inlet section thereof and for the effective cross-sectional area of the inlet section to be larger than the effective cross-sectional area of the inlet to the annular flow path, for the effective cross sectional area of the outlet of the flow path to be larger than that of the inlet of the annular flow path and to be larger or smaller than the effective cross-sectional area of the inlet section of the flow path.
24. A scrubber as claimed in claim 23 in which the flow path has an outlet section with a larger effective cross sectional area than the outlet of the annular flow path.
25. The invention extends to a scrubbing method including the steps of:

providing a conically shaped flow path in a body between an inlet and an outlet;

locating at least part of an insert centrally in the conically shaped flow path to form, in cross-section, an annular flow path between an outer surface of the insert an inner surface of the conically shaped part of the body; and

creating rotational flow in the annular flow path with rotation means.

26. A scrubbing method as claimed in claim 25 in which the annular flow path increases in effective cross-sectional surface area from the inlet to the outlet.

27. A scrubbing method as claimed in any one of claims 25 or 26 in which the step of creating rotational flow includes creating rotational air flow spiraling through the annular flow path from the inlet to the outlet.

28. A scrubbing method as claimed in any one of claims 25 to 27 in which the step of placing the at least part of the insert in the conically shaped part includes adjusting the axial position of the insert inside the conically shaped part so that a larger or smaller section of the insert locates in the conically shaped part and securing the insert in position, once adjusted.

29. A scrubbing method as claimed in any one of claims 25 to 28 including the step of introducing liquid mist or spray into the annular flow path or at or in front of the inlet.

30. A scrubbing method as claimed in any one of claims 25 to 29 in which an outer surface of the insert is shaped complementary to the conical part, but smaller in diameter than the conical part.

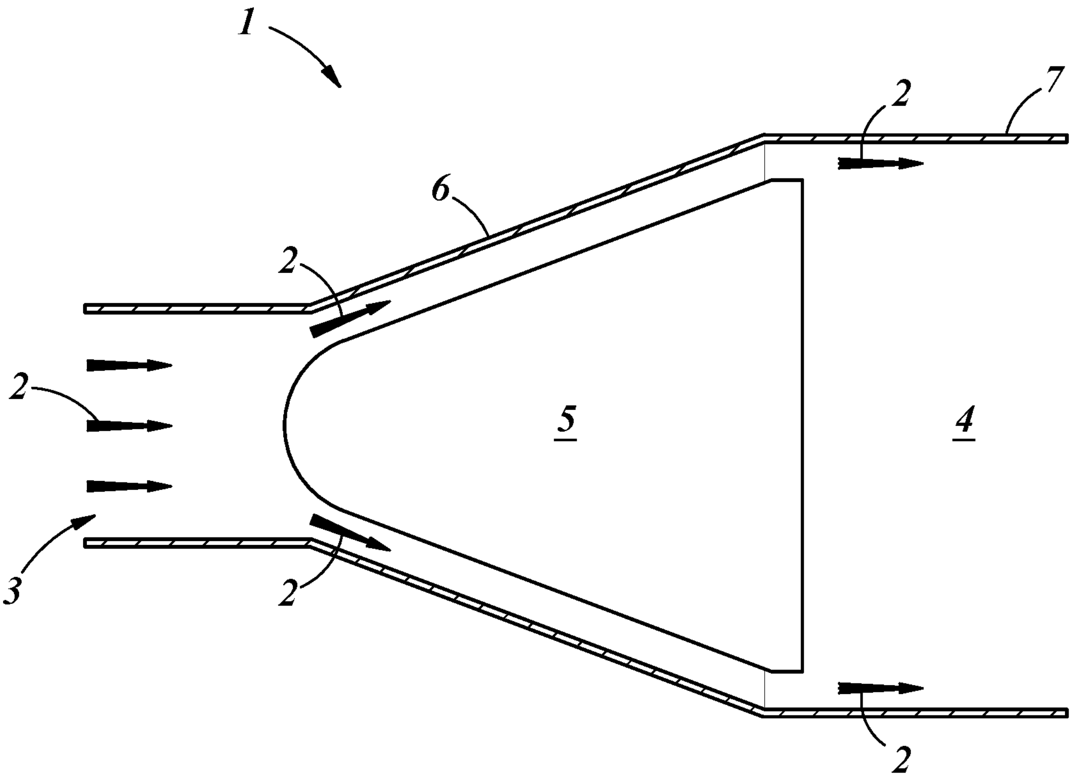

FIGURE 1

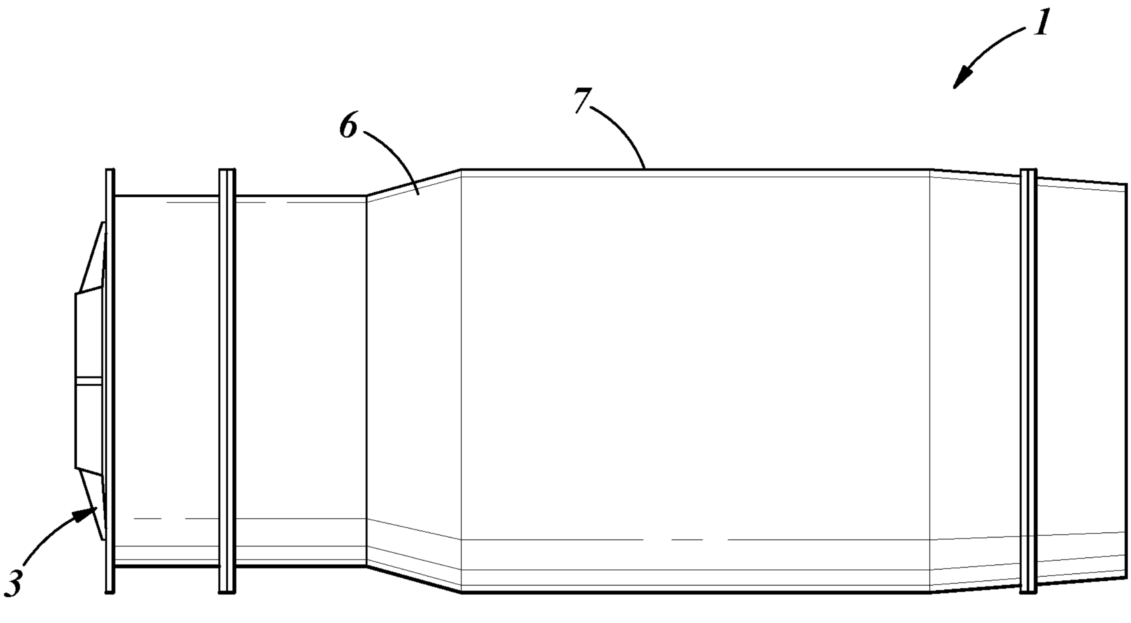

FIGURE 2

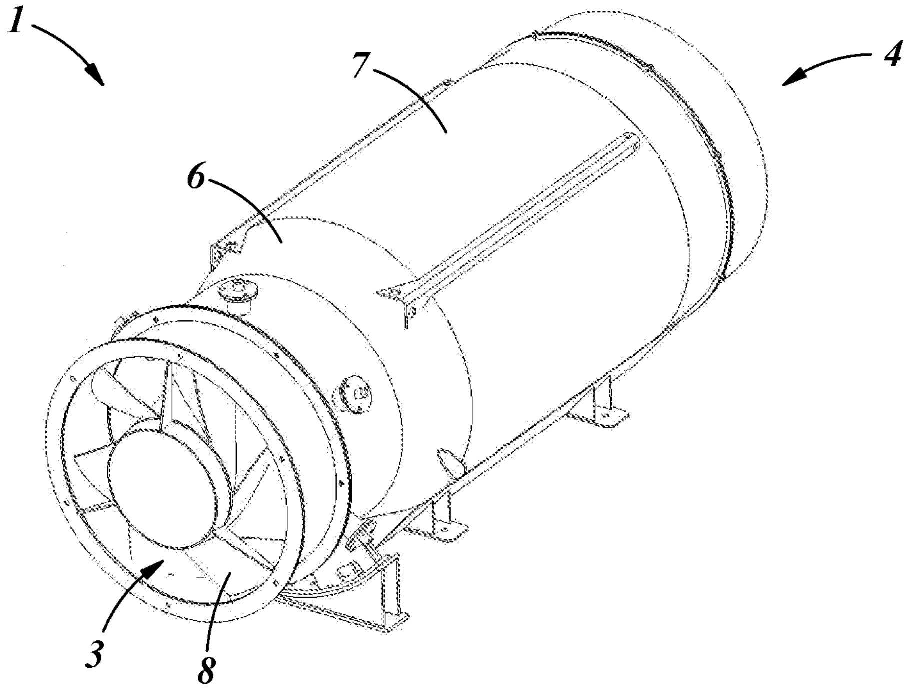

FIGURE 3

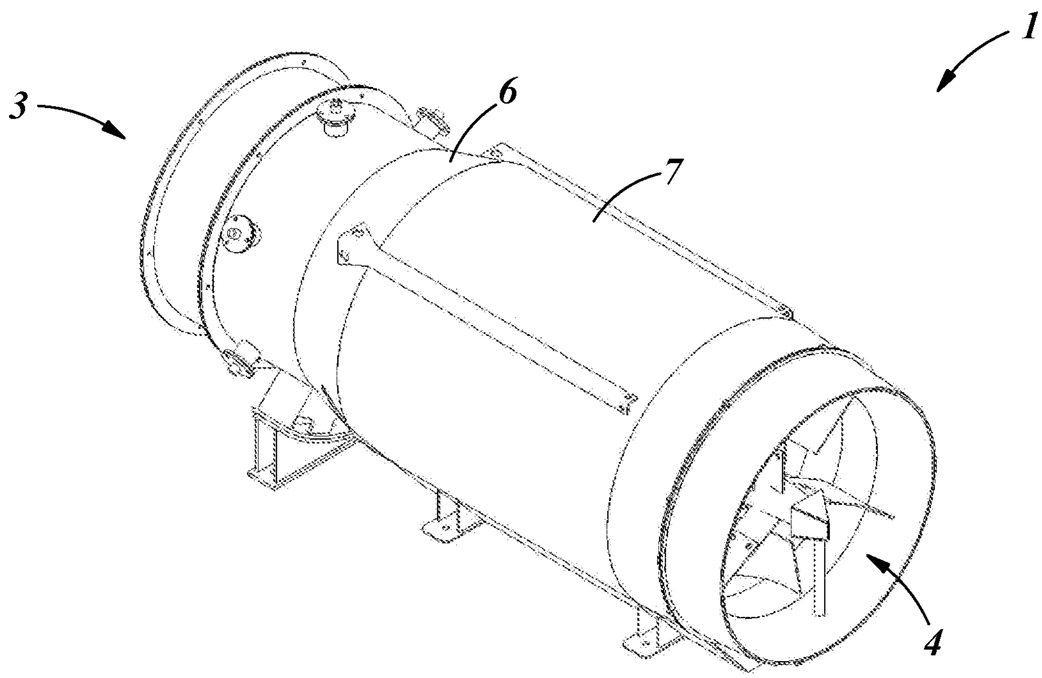

FIGURE 4

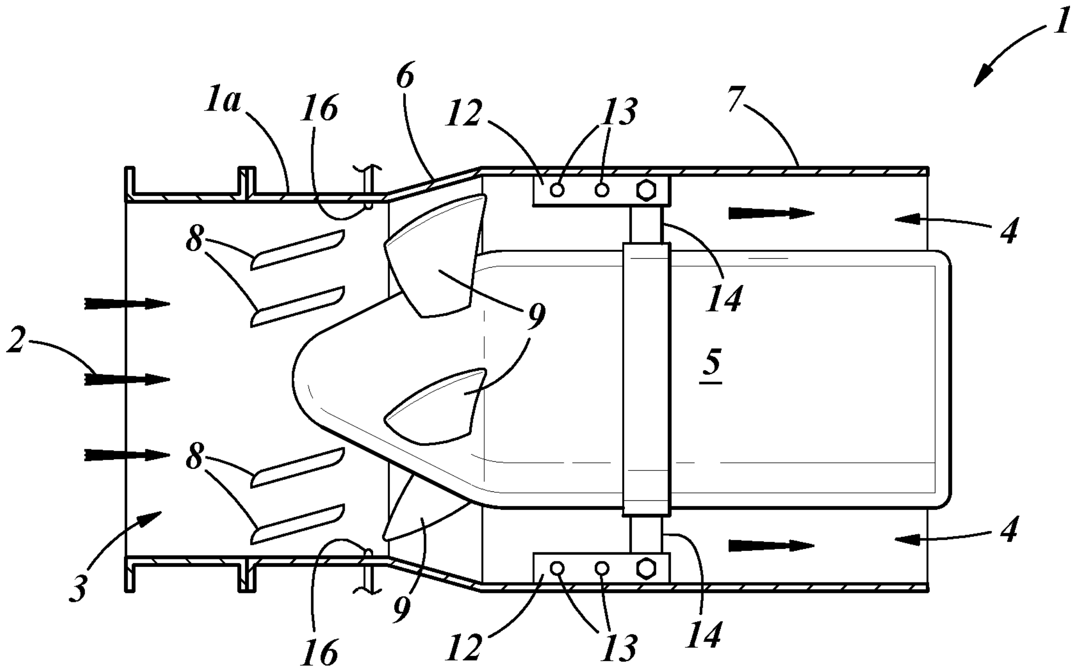

FIGURE 5

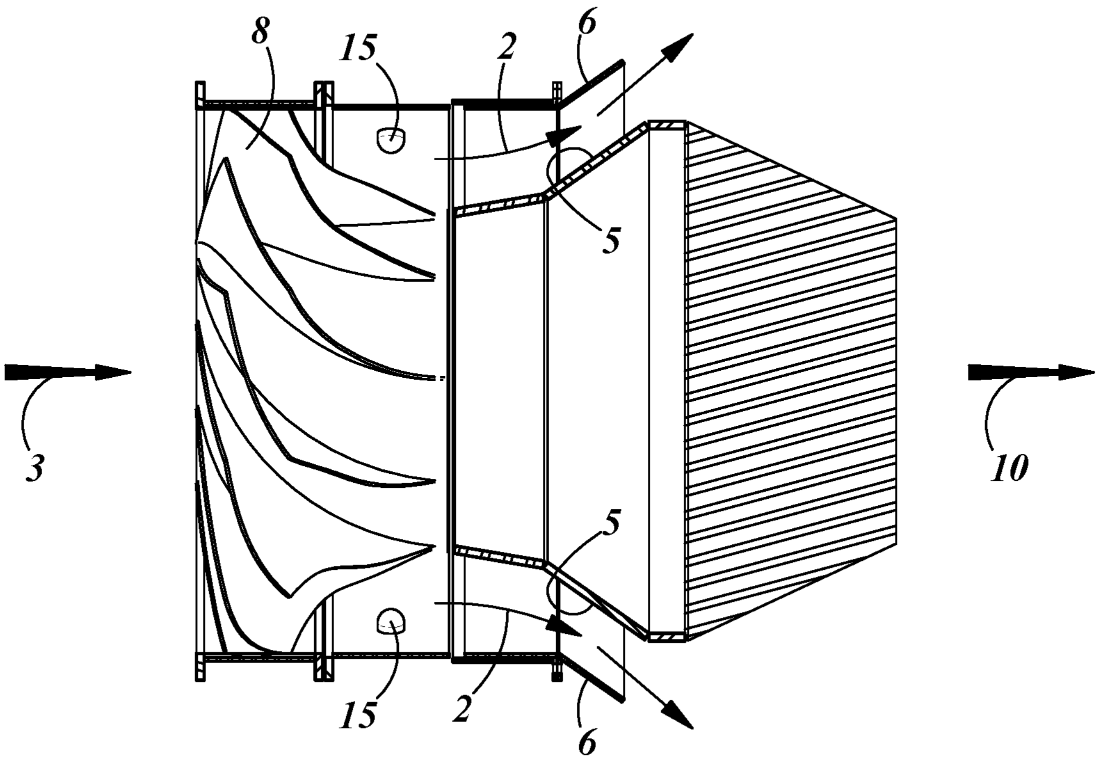

FIGURE 6

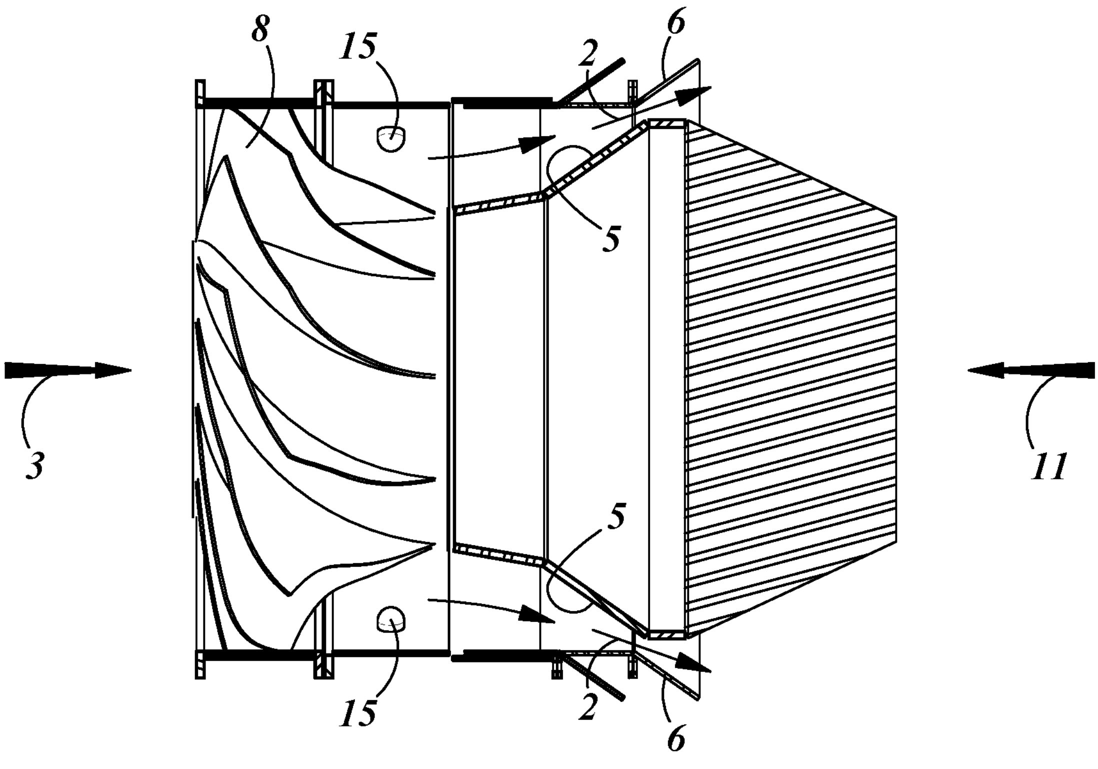

FIGURE 7

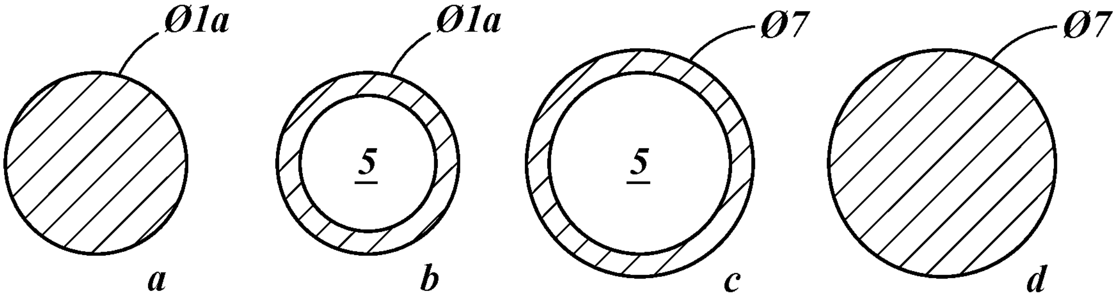

FIGURE 8

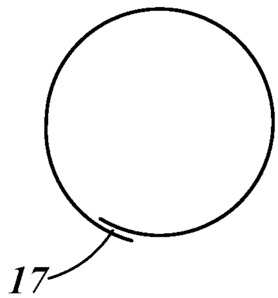

FIGURE 9