(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 390 264 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
26.06.2024 Bulletin 2024/26

(21) Application number: **23217642.0**

(22) Date of filing: **18.12.2023**

(51) International Patent Classification (IPC):
F24F 13/062 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F24F 13/062

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **22.12.2022 BE 202206062**

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(54) A VALVE DEVICE FOR USE IN A VENTILATION SYSTEM

(57) A valve device for use in a ventilation system. The valve device comprises: a base (44, 46) configured to connect to a pipe and an airflow guide (50) directed toward the base. The base has an inner wall (66) with a variable diameter that decreases from an initial value (R_1) on the pipe to a minimum value (R_2) and then increases to a maximum value (R_3) on the output side. The airflow guide is substantially bell-shaped in cross-section with a top directed towards the base. A hypothetical disc (5) positioned at the constriction of the inner wall intersects the airflow guide in an intersection line (74). Providing such a constriction ensures a concentration of the flow near the top of the airflow guide, while the placement of the top prevents the concentrated air from colliding directly with it. These effects together ensure an improved air flow over the valve device.

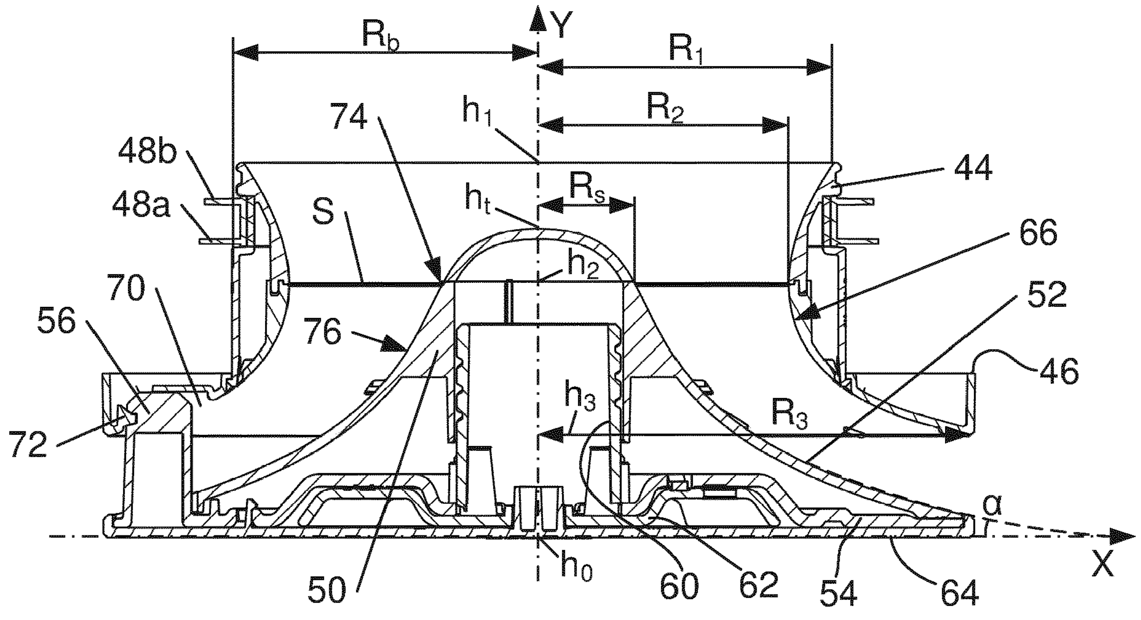


Fig. 4

Description

Technical field

[0001] The present invention relates to a valve device for use in a ventilation system. The present invention also relates to a ventilation system comprising one or more such valve devices.

State of the art

[0002] Valve devices are used in ventilation systems for the transition between the pipes of the ventilation system and the space into which air is to be blown or from which air is to be extracted. Various types of ventilation systems are known, such as B-type, C-type or D-type systems. Depending on the ventilation system used, air can be: exclusively blown through (positive input ventilation) a valve device to a space (B-type); exclusively drawn through (extraction) the valve device from a space (C-type); or a sequential combination of both (D-type). Often, a valve device is specifically designed to optimally perform in one of the two modes, i.e. extraction or positive input.

[0003] A known valve device for use in a ventilation system comprises a base, configured to be placed in an opening in a wall, in particular a ceiling, of a space. The base is provided with: a first circular opening, configured for connection to a pipe of the ventilation system; a second circular opening, located opposite the first circular opening; and an inner wall, extending between the circular openings, which inner wall is substantially rotationally symmetrical with respect to a central axis. The valve device further comprises an airflow guide, mounted on the base, which airflow guide comprises a guide wall directed towards the base. The guide wall is substantially rotationally symmetrical with respect to said central axis and a cross-section through the guide wall in a plane comprising the central axis follows a substantially bell-shaped curve, wherein a central part of the guide wall is closer to the first circular opening than an outer part of the guide wall.

[0004] Such a valve device is disclosed in EP 2 503 255 B1 and EP 3 575 702 A1. A number of problems and/or desired effects are known in the context of valve devices.

[0005] A problem is related to noise, caused by the valve device. In practice, the valve device forms a constriction with respect to the pipe diameter. Such a constriction causes an acceleration of the air flow and can give rise to vibrations in the valve device that generate noise. This problem is especially relevant in positive input ventilation since, in extraction, the noise generated is extracted towards the pipes and thus away from the space.

[0006] A problem relates to the pressure drop across the valve device. This is again mainly a problem in positive input ventilation. Due to the constriction formed by the valve device, there is resistance in the air flow, which causes a pressure drop. This is preferably as low as possible because, in this way, the ventilation system has to blow the air less hard and can therefore save energy.

[0007] A problem is the creation of dead zones and/or vortices in the air flow. This can occur in both positive input ventilation and extraction. Both of these effects can contribute to increasing pressure drop and generating noise.

[0008] Furthermore, most valve devices are adjustable in the sense that their outgoing (in positive input ventilation) or incoming (in extraction) opening is adjustable in surface area, i.e. as a result of which the maximum flow rate that can flow through the valve device varies. The setting is typically made during installation of the ventilation system and is done depending on the volume of the space and/or the properties of a central ventilation module. Furthermore, dynamically adjustable valve devices are also known. Adjustments to the flow rate often also affect the air flow and sometimes lead to unforeseen and undesirable side effects, such as increased pressure drop, increased noise, etc.

[0009] A valve device according to the preamble of claim 1 is disclosed in WO 2022/243351 A1. The flow rate through the disclosed valve device is adjustable by means of an annular flow regulator, placed around the top of the airflow guide. The annular flow regulator therefore creates an obstacle within the base that affects the airflow. A rotation of the airflow guide causes a shift of the annular flow regulator relative to the airflow guide, which reduces or increases the flow rate.

Description of the invention

[0010] It is therefore an object of the present invention to provide a valve device for use in a ventilation system wherein the air flow is optimized, in particular for applications in both extraction and positive input ventilation.

[0011] This objective is achieved by the fact that said bell-shaped curve is substantially parallel to said inner wall for an outer part of the guide wall.

[0012] The substantial alignment firstly ensures an increase in the flow rate (in positive input ventilation) such that an acceleration of the air flow is avoided.

[0013] In addition, this is advantageous in a valve device as described below, wherein the airflow guide is slidable relative to the base for regulating a flow rate over the valve device. The mutual orientation of the guide wall and the inner wall is then independent of the position of the airflow guide.

[0014] To determine whether the inner wall and the bell-shaped curve are substantially parallel to each other, areas that are substantially equidistant from the central axis, should be compared.

[0015] In the context of the present invention, a distance between the inner wall and the central axis, measured perpendicular to the central axis: has a first value at the first circular opening; has a maximum value at the second circular opening; and has a minimum value at an intermediate location between the circular openings, which first value is greater than the minimum value and smaller than the maximum value, wherein said distance between the inner wall and the central axis, measured perpendicular to the central axis, decreases monotonically from the first value to the minimum value and increasing monotonically from the minimum value to the maximum value, and wherein a hypothetical disk, perpendicular to the central axis with said minimum value as a radius positioned at said intermediate location, intersects the guide wall in an intersection line.

[0016] The inventors have determined that such a design of the inner wall and placement of the airflow guide achieves a desired air flow, both in positive input ventilation and extraction. More in particular, providing a constriction in the inner wall of the base (hereinafter also referred to as the base body) ensures a concentration of the flow (in positive input ventilation) near the top of the airflow guide. The acceleration of the air flow as a result of such a narrow passage prevents an acceleration near the outlet of the valve device. This results in less noise generation. The airflow is also pushed towards the airflow guide, through which it is then diverted to the exit. This prevents or at least reduces airflow separation. Furthermore, the top of the airflow guide is located in front of (seen in the airflow direction in positive input ventilation) the constriction of the base such that the concentration of the airflow is prevented from colliding with the top of the airflow guide, which could be the case with a valve device wherein the top of the airflow guide is located after the constriction.

[0017] In an embodiment of the present invention, a cross-section through the inner wall in said plane follows a substantially smooth curve. An airflow guide with a smooth surface is advantageous for achieving a stable air flow.

[0018] In an embodiment of the present invention, said distance between the inner wall and the central axis, measured perpendicular to the central axis, strictly monotonically decreases from the first value to the minimum value and strictly monotonically increases from the minimum value to the maximum value. This strict decrease/increase results in an inner wall that is mainly smooth, which, as stated above, is advantageous for obtaining a stable air flow.

[0019] In an embodiment of the present invention, the guide wall has a maximum radius that is substantially the same as said maximum value. The walls between which the air is guided have the same external dimensions and therefore extend almost the same distance. Therefore, no situation exists wherein one of the two airflow guide walls falls away, which could have an adverse effect on the air flow, such as deflection at the falling wall and therefore separation from the other wall.

[0020] In an embodiment of the present invention, said outer part of the guide wall comprises at least the part of the guide wall that is located at a distance from the central axis, measured perpendicular to the central axis, which distance is greater than 90%, in particular 80% and more in particular 75% of said maximum value. In other words, preferably the outer 25% of the guide wall is parallel to the inner wall. This maximizes the mutually parallel area, which promotes a calm flow.

[0021] In an embodiment of the present invention, the guide wall at its end forms an angle with respect to a perpendicular plane to the central axis, which angle is between 5 ° and 35 °, which angle is in particular at least 10° or 13 °, which angle is in particular at most 30 ° or 25 °, which angle is more in particular approximately 15 °. This angle mainly determines the direction of outgoing air in positive input ventilation. The direction is sufficiently away from the ceiling to avoid dirt deposits over time, but not too strongly downwards so as not to blow directly on the people below.

[0022] In an embodiment of the present invention, said intersection line is circular with a radius that is between 10 % and 50 % of said first value, which radius is in particular at least 20 % or 25 % of said first value, which radius is in particular at most 40 % or 35 % of said first value, which radius is more in particular approximately 30 % of said first value. Such a radius ensures that a sufficient part of the airflow guide is located in front of the narrowest passage, seen in the air flow in positive input ventilation. Such a large part of the top of the airflow guide above the constriction is further advantageous in extraction and contributes to avoiding or reducing the separation of the air flow from the airflow guide.

[0023] In an embodiment of the present invention, said substantially bell-shaped curve comprises an inflection point on either side of the central axis, which inflection points together form an inflection line of the guide wall, wherein said inflection line is located near said intersection line or wherein said inflection line is located closer to the first circular opening than said intersection line. The placement of this inflection line near or above the intersection line ensures that the constriction concentrates the air to the airflow guide at a location where it transitions to a convex wall. The airflow in positive input ventilation therefore flows along a smooth monotonous surface without inflection transition, which avoids disruption of the airflow. There is a further advantage in extraction as the airflow typically is set free once past the inflection line and is then already near or beyond the narrowest zone of the base.

[0024] In an embodiment of the present invention, said mainly bell-shaped curve is described by a Gaussian function or a Cauchy function or a linear combination thereof:

$$y = \left(e^{-\frac{1}{2}\left(\frac{x}{\sigma}\right)^2}\right) * w_G + \left(\frac{1}{1 + \left({}^{x}/_{\gamma}\right)^2}\right) * w_C$$

[0025] wherein *x* describes the distance from the central axis, measured perpendicular to the central axis, *y* describes the distance along the central axis, σ is the standard deviation of the Gaussian function, γ is the scale parameter for the half-width of the Cauchy function, and w_G and w_C are weight parameters of the linear combination. Preferably, w_G and w_C are each a positive real number whose sum is approximately equal to a height of the guide wall, measured along the central axis, wherein σ is a positive real number that is between 20 % and 60 % of said minimum value, wherein σ is in particular at least 30 % or 35 % of said minimum value, wherein σ in particular at most 50 % or 45 % of said minimum value, wherein σ is in particular approximately 40 % of said minimum value, and wherein γ is a positive real number that is between 50 % and 90 % of said minimum value, wherein γ is in particular at least 60 % or 65 % of said minimum value, wherein γ is in particular at most 80 % or 75 % of said minimum value, wherein γ is in particular approximately 70 % of said minimum value. The inventors generally established that the design of the guide wall in the outer regions (i.e. radially beyond the inflection line) is important for the airflow in positive input ventilation while the design of the guide wall in the centre (i.e. radially within the inflection line) is important for the air flow in extraction. To obtain the desired design, a linear combination of a Gauss function and a Cauchy function proved useful because the relatively heavy tail of the Gauss function can be weakened due to the relatively lighter tail of the Cauchy function. The values of σ and γ are such that the inflection points of the respective functions are located near the intersection line of the guide wall and the hypothetical disk at the location of the narrowed inner wall since, as already stated above, this is advantageous for the air flow in extraction.

[0026] In an embodiment of the present invention, said minimum value is between 60 % and 95 % of said first value, which minimum value is in particular at least 70 % or 75 % or 80 % of said first value, which minimum value is in particular at most 90 % or 85 % of said first value, which minimum value is more in particular approximately 82 % or 83 % of said first value. Such a value appears to provide sufficient constriction to concentrate the air flow (in positive input ventilation), but not too much constriction, which would lead to an increased pressure drop.

[0027] In an embodiment of the present invention, the valve device further comprises a support that is fixedly attached to the base, wherein the guide wall is slidably attached to the support. Preferably, the support is firmly attached to the base by means of a number of fins that protrude through the guide wall, which fins have a smooth surface. A sliding guide wall is advantageous for regulating the flow through a valve device. A shift of the guide wall creates a smaller or larger volume available where air can flow, such that the flow rate varies at a constant flow rate. This flow control does not require additional obstacles in the flow path, which obstacles can lead to unwanted noise. Smooth fins avoid or reduce the risk of negative airflow influences.

[0028] The advantages of the embodiments described above are also achieved with a ventilation system for a building comprising at least one space, the ventilation system comprising: a ventilation unit; a network of pipes connected to the ventilation unit; and a valve device as described above, placed in a wall, in particular a ceiling, of said at least one space and connected to a pipe of said network of pipes.

[0029] In an embodiment of the present invention, the ventilation system has a blowing state (positive input ventilation) and an extraction state (extraction), wherein, in the blowing state, the ventilation system is configured to blow air through the valve device to said at least one space and wherein, in the extraction state, the ventilation system is configured to extract air through the valve device from said at least one space. Preferably, the ventilation system is configured to blow air (positive input ventilation) through the valve device to said at least one space with a nominal flow rate, which nominal flow rate is between 50 m^3 per hour and 1 m^3 per hour, which nominal flow rate is in particular at least 60 m^3 per hour or 70 m^3 per hour, which nominal flow rate is in particular at most 90 m^3 per hour or 80 m^3 per hour, which nominal flow rate is more in particular approximately 75 m^3 per hour. The advantages of a D-type ventilation system are known to those skilled in the art and the valve device according to the present invention is in particular suitable for use in both positive input ventilation and extraction. The nominal flow rates described above further allow the use of fewer valve devices per space, compared to current valve devices that typically have a lower nominal flow rate.

Brief description of the drawings

[0030] The invention will hereinafter be explained in further detail on the basis of the following description and the accompanying drawings.

Figure 1 shows a schematic representation of a residential unit comprising a ventilation system with multiple valve devices according to the present invention.

Figure 2 shows an exploded view of a valve device according to the present invention.
Figure 3 shows a top view of a valve device according to the present invention.
Figure 4 shows a section through the valve device of Figure 3 along the plane 'IV' indicated in Figure 3.
Figure 5A shows a perspective view of a valve device according to the present invention with a portion of the fin removed.
Figure 5B shows a detail of Figure 5A.
Figure 6 shows a perspective view of a valve device according to the present invention with a tool for moving the airflow guide.
Figure 7A shows an overview of the air flow in positive input ventilation in an assembly of pipe and a known valve device.
Figure 7B shows a detail of Figure 7A.
Figures 8A to 8E show an overview of the air flow in positive input ventilation in various valve devices according to the present invention.
Figure 9A shows an overview of the air flow in extraction in an assembly of pipe and a valve device according to the present invention.
Figure 9B shows a detail of Figure 9A.
Figure 9C shows an overview of the air flow in extraction in a valve device according to the present invention.

Embodiments of the invention

[0031] The present invention will hereinafter be described with reference to specific embodiments and with reference to certain drawings, but the invention is not limited thereto and is only defined by the claims. The drawings shown here are only schematic representations and are not restrictive. In the drawings the dimensions of certain components may be shown enlarged, which means that the components in question are not shown to scale and this is for illustrative purposes only. The dimensions and relative dimensions do not necessarily correspond to actual practical embodiments of the invention.

[0032] In addition, terms such as "first", "second", "third", and the like are used in the description and in the claims to distinguish between similar elements and not necessarily to indicate a sequential or chronological order. The terms herein are interchangeable in appropriate circumstances, and embodiments of the invention may operate in different sequences than those described or illustrated herein.

[0033] In addition, terms such as "top," "bottom," "above," "below," and the like are used in the description and in the claims for descriptive purposes. The terms so used are interchangeable in appropriate circumstances, and the embodiments of the invention may operate in other orientations than those described or illustrated herein.

[0034] The term "comprising" and derivative terms, as used in the claims, shall not be construed as being limited to the means set forth in each case thereafter; the term does not exclude other elements or steps. The term shall be interpreted as a specification of the stated properties, integers, steps, or components referred to, without excluding the presence or inclusion of one or more additional properties, integers, steps, or components, or groups thereof. The scope of an expression such as "a device comprising means A and B" is therefore not limited solely to devices consisting purely of components A and B. What is meant, on the other hand, is that, as far as the present invention is concerned, the only relevant components are A and B.

[0035] The terms "substantially" or "mainly" are intended to be synonymous and comprise variations of +/- 10 % or less, preferably +/-5 % or less, more preferably +/-1 % or less, and even more preferably +/-0.1 % or less, of the specified condition, to the extent that the variations are applicable to function in the present invention. It should be understood that the term "substantially A" or "substantially A" is intended to comprise "A".

[0036] Figure 1 shows a schematic representation of a residential unit 1 comprising a ventilation system. In the embodiment shown, the residential unit 1 comprises three spaces 12, 14, 16. These can be physically separate spaces (e.g. a bedroom, a living space, a kitchen, a bathroom, etc.), but they can also be entire floors of the residential unit 20 (e.g. the ground floor) or a combination of both. The ventilation system comprises on the one hand a central ventilation module 10 and on the other hand a number of conduits 20, 22, 24, 26, 28, 30, 32, 34. Conduit 20 is connected to the central ventilation module 10 and serves for the supply of outside air; conduit 22 is connected to the central ventilation module 10 and serves for the discharge of air to the outside environment; conduit 24 is connected to the central ventilation module 10 and serves for the supply of air to space 14; conduit 26 is connected to the central ventilation module 10 and serves for the supply of air to space 12; conduit 28 is connected to the central ventilation module 10 and serves for the discharge of air from space 14; conduit 30 is connected to the central ventilation module 10 and serves for the discharge of air from space 16; conduit 32 is connected to the central ventilation module 10 and serves for the discharge of air from space 12; and conduit 34 forms a connection between spaces 14, 16 and serves for the supply of air to space 16. Typically, on each of the conduits 20, 22, 24, 26, 28, 30, 32, 34 an adjustable valve (not shown) is provided for regulating the air flow to and from a space.

[0037] Figure 1 further shows that each conduit 20, 22, 24, 26, 28, 30, 32, 34 is provided with a valve device 40 at the end leading to a space 12, 14, 16. Preferably, in each case, this is a valve device 40 according to the present invention as described below, but other ventilation valves or ventilation grilles are also possible, provided that the ventilation system comprises at least one valve device 40 according to the present invention.

[0038] Figure 1 illustrates a D-type ventilation system, also known as balanced ventilation, and is a ventilation based on mechanical supply and mechanical exhaust via the central ventilation module 10, typically with heat recovery ventilation (HRV) and/or energy recovery ventilation (Energy Recovery Ventilation - ERV). Such D-type systems can therefore lead to an air flow to a specific space (i.e. blowing air into a space), hereinafter also referred to as " positive input ventilation ", or an air flow from a specific space (i.e. extracting air from a space), hereinafter also referred to as "extraction". The valve device 40 according to the present invention as described below is in particular designed to provide optimal air flow for both positive input ventilation (blowing air from a space) and extraction (extracting air from a space). However, it should be clear that the valve device according to the present invention is not limited for use in a D-type ventilation system, but can also be used, for example, in a B-type or C-type ventilation system wherein the valve device serves exclusively for positive input ventilation (B -type system) or extraction (C-type system).

[0039] Figure 2 shows the various components of a valve device 40 according to the present invention. The valve device 40 comprises a base body 42 constructed from a tubular element 44 and a flange-shaped element 46. The tubular element 44 extends between a first opening 44a and a second opening 44b, which are opposite each other. In use, the tubular element 44 is placed in an opening in a wall, in particular a ceiling, of a space of the building 1. The first opening 44a is located at the rear of the wall. The tubular element 46 extends between a first opening 46a and a second opening 46b, which are opposite each other. The flange-shaped element 46 is fixedly attached to the tubular element 44, with the second opening 44b of the tubular element 44 connecting to the first opening 46a of the flange-shaped element 46. In use, the flange-shaped element 46 is normally attached with the top of the annular flange wall 46c to a front (i.e. the visible side) of the wall.

[0040] The tubular element 44 is intended to be connected to a pipe of the ventilation system, wherein the first opening 44a and a part of the peripheral wall 44c are placed inside the pipe. The shown valve device 40 further comprises a seal 48, positioned on the outside of the peripheral wall 44c. The shown seal 48 comprises a closed ring 48a that ensures a good seal between the pipe and the tubular element 44. The shown seal 48 further comprises a serrated ring 48b with protruding fins that ensure an attachment of the tubular element 44 to the pipe. The fins in the embodiment shown become narrower as they extend further. This is advantageous from a production point of view because such a shape can be removed more easily from an injection mould compared to a shape with the fins increasing towards the outside. The closed ring 48a is typically thinner than the serrated ring 48b. In this way, the closed ring 48a is more flexible to ensure a good seal and the serrated ring 48b (including the fins) is more rigid to ensure sufficient fixation of the base body 42 on the pipe.

[0041] In the embodiment shown, the seal 48 is manufactured integrally. This reduces the risk of both rings 48a, 48b becoming separated from each other. The seal 48 may be manufactured via injection moulding. The seal 48 is therefore preferably made of a thermoplastic material, such as polyurethane rubber.

[0042] The design of the seal 48, in particular the presence of the serrated ring 48b, is advantageous compared to a seal with two closed rings. The valve device 40 must be regularly removed from the pipe, e.g. for the annual cleaning of the pipes, for repairs, etc. The serrated ring 48b exerts a lower force for fixation compared to a closed ring, such that the valve device 40 is easier to remove. Given the need to regularly avoid the valve device 40, it is further advantageous to attach the valve device 40 without additional means (e.g. bolts, screws, glue, etc.) that can cause damage to the pipes, the wall, the valve device, etc.

[0043] The valve device 40 further comprises an airflow guide 50 positioned opposite the flange-shaped element 46. The airflow guide 50 comprises a guide wall 52 that is directed towards the flange-shaped element 46. The airflow guide 50 is attached to the base body 42 by means of a mounting element 54 that is fixed to the base body 42 by means of upright fins 56 that protrude through openings 58 in the guide wall 52.

[0044] In the embodiment shown, the airflow guide 50 is slidable relative to the base body 42. This allows the flow passage through the valve device 40 to be varied. This is typically done when installing the ventilation system depending on the flow of air to or from the space. For sliding purposes, the airflow guide 50 is placed on a rotatable support 60 which is provided with a screw thread on its outside. The airflow guide 50 is provided with a corresponding screw thread on its inside (not shown). The support 60 is placed on the mounting element 54 at the top thereof, with an adjustment element 62 at the bottom of the mounting element 54. The support 60 and the adjustment element 62 are firmly connected to each other. By turning the control element 62, there is a corresponding rotation of the support 60, which, since the fins 56 prevent the airflow guide 50 from rotating, the screw threads ensure a displacement of the airflow guide 50.

[0045] In the embodiment shown, the control element 62 is provided with a recess 62a (shown in Figure 6) into which a tool 63 (e.g. a long rod with a suitable head) fits. In this way, a user (typically an installer) can directly operate the control element 62 from a ground surface in the space without the need for a ladder or the like. In the embodiment shown, the control element 62 is further provided with several radial protrusions 62b. These provide a number of predetermined positions of the airflow guide 50 relative to the base body 42.

[0046] A top view of the valve device 40 is shown in Figure 3 and a cross-section is shown in Figure 4. The design of the guide wall 52 and the inner wall 66 of the base body 42 will be described with reference to Figure 4. In general, the *x* coordinate is used hereinafter for representation of the distance between one of the surfaces and the central axis 68 and the *y* coordinate for representing the distance along the central axis 68.

[0047] As already described above, the invention generally relates to a valve device 40 that is suitable for both positive input ventilation and extraction. This means that, in use, the valve device 40 preferably causes as little additional noise as possible; and/or that the pressure loss of the air flow over the valve device 40 is preferably as low as possible; and/or that, in positive input ventilation, the air flow has a desired direction (e.g. not too much downwards as this can lead to a flow aimed at a person or not too much towards the wall or ceiling to avoid dirt deposits, etc.) and this in the various positions of the airflow guide 50 relative to the base body 42. Crucial to realizing these technical effects is the design of the guide wall 52 and the inner wall 66 of the base body 42.

[0048] In general, the guide wall 52 is rotationally symmetrical with respect to the central axis 68, wherein a cross-section through the guide wall 52 in a plane comprising the central axis 68 (as shown in Figure 4) follows a substantially bell-shaped curve. The top of the bell shape (hereinafter this height is indicated by h_t) is directed towards the base body 42, i.e. a central part of the guide wall 52 is closer to the first circular opening 44a than an outer part of the guide wall 52.

[0049] In general, the inner wall 66 of the base body 42 is rotationally symmetrical with respect to the central axis 68 and is provided with a narrowed zone. More in particular, the radius of the inner wall 66 decreases from a first value R_1 at the first opening 44a (hereinafter this height is denoted by h_1) to a minimum value R_2 at an intermediate position h_2 and then increases to a maximum value R_3 at the second opening 46b (hereinafter this height is indicated as h_3).

[0050] In the embodiment shown, the monotonic decrease and the monotonic increase are a strict decrease/increase such that the inner wall 66 forms a smooth surface. A smooth surface contributes to the creation of a constant airflow (e.g. avoiding vortices and/or turbulence) as well as to the avoidance of dead zones in the airflow. There is an exception to the smooth surface, namely at the location where the fins 56 are attached to the base body 42, as shown in Figure 4, where an indentation 70 is provided in the wall. This indentation 70 provides the necessary space such that the fin 56 is attached to the base body 42 by means of hook means 72.

[0051] The first value R_1 at the first opening 44a is generally determined as a function of the diameter of the pipe to which the valve device is connected. As already described above, the tubular part 44 is inserted into the pipe, such that the first value R_1 is smaller than the radius of the pipe, as well as the outer diameter R_b of the tubular element 44 that is smaller than the radius of the pipe. In the version shown, the pipe diameter is 125 mm and is R_b 120 mm, but other standard values are also possible. The values R_1 and R_b are virtually the same and are a consequence of the wall thickness of the tubular element 44.

[0052] The minimum value R_2 is generally between 60 % and 95 % of said first value R_1, which minimum value R_2 is in particular at least 70 % or 75 % or 80 % of said first value R_1, which minimum value R_2 is in particular at most 90 % or 85 % of said first value, which minimum value R_2 is more in particular approximately 82 % or 83 % of said first value R_1.

[0053] Generally, the top of the guide wall 52 is located in the volume defined between the positions h_1 and h_2, i.e. the top of the guide wall 52 is generally located between the first opening 44a and the narrowest part of the inner wall 66. A way to describe this is that a hypothetical disk, perpendicular *S* to the central axis 68 with said minimum value R_2 as radius positioned at said intermediate location , intersects the h_2 guide wall 52 in an intersection line 74. Given the rotational symmetry of the guide wall 52, this is therefore a circular intersection line 74 with a radius R_S. The existence of such an intersection line is a necessary condition for the top of the guide wall 52 to be higher than the narrowest part of the inner wall 66. This condition must be met for every possible position of the guide wall 52 relative to the base body 42.

[0054] In the embodiment shown, the guide wall 52 is a smooth surface. A smooth surface contributes to the creation of a constant airflow (e.g. avoiding vortices and/or turbulence) as well as to the avoidance of dead zones in the airflow. There is an exception to the smooth surface, namely at the location where the fins 56 protrude through the guide wall 52.

[0055] The radius R_S of the circular intersection line 74 is between 10 % and 50 % of said first value R_1, which radius R_S is in particular at least 20 % or 25 % of said first value R_1, which radius R_S is in particular at most 40 % or 35 % of said first value R_1, which radius R_S is more in particular approximately 30 % of said first value R_1. These dimensions are determined in the maximum extended position of the guide wall 52 relative to the base body 42, which position is shown in Figure 4.

[0056] According to the present invention, an outer part of the guide wall 52 is substantially parallel to the inner wall 66 located immediately above it. This contributes to a constant air flow, regardless of the position of guide wall 52 relative to the base body 42. The outer part of the guide wall 52 is located at a distance from the central axis 68, measured perpendicular to the central axis 68, which distance is greater than 90 %, in particular 80 %, and more in particular 75 %, of said maximum value R_3.

[0057] This is best shown in Figure 4, where the outer parts of the inner wall 66 and the guide wall 68, i.e. the parts that are located at a distance of more than 0.75 * R_3 , are virtually parallel to each other. In other words, the part of the inner wall 66 that is located at a distance of 0.9 * R_3 from the central axis 68 is substantially parallel to the corresponding part of the guide wall 68, i.e. the part of the guide wall 68 that is located at a distance of 0.9 * R_3 of the centre axis 68.

[0058] In particular, the guide wall 52 has a maximum radius that is substantially the same as the maximum value mentioned R_3. This prevents the airflow from suddenly only passing along a wall, which can lead to turbulence and/or vortices.

[0059] In the embodiment shown, the guide wall 52 at its end forms an angle α relative to a perpendicular plane to the central axis 68, which angle is between 5° and 35°, which angle α is in particular at least 10° or 13°, which angle α is in particular at most 30 ° or 25 °, which angle α is more in particular approximately 15 °. This angle ensures the desired outflow direction of the air in the pulse.

[0060] The guide wall 52 comprises, in its cross-section, an inflection point 76 on either side of the central axis 68, which together form a circular inflection line of the guide wall 52. The inflection line is located nearby (e.g. with a radius that differs by at most 15 % from the value R_S) the intersection line 74 such that the transition of the guide wall 52 between a convex top and a concave outer wall is located near the narrowest zone of the inner wall 66. The inflection line can also be located above the intersection line 74.

[0061] A functional description of the cross-section of the guide wall 52 is best described by a Gaussian function or a Cauchy function or a linear combination thereof:

$$y = \left(e^{-\frac{1}{2}\left(\frac{x}{\sigma}\right)^2}\right) * w_G + \left(\frac{1}{1 + \left(x/_{\gamma}\right)^2}\right) * w_C + C$$

wherein describes x the distance from the central axis, measured perpendicular to the central axis, y describes the distance along the central axis, σ is the standard deviation of the Gaussian function, γ is the scale parameter for the half-width of the Cauchy function, w_G and are weight parameters of w_C the linear combination, and C is a parameter that determines 0 the $y$line or axis. Accordingly, w_G and w_C are each a positive real number whose sum is approximately equal to a height h_t of the guide wall 52, measured along the central axis 68, wherein $\sigma$is a positive real number that is between 20 % and 60 % of said minimum value, wherein R_2 is in particular at least 30 % or 35 % of said minimum value, wherein $\sigma$is in particular at most 50 % or 45 % of said minimum value R_2 , wherein $\sigma$is more in particular approximately 40 % of said minimum value R_2 , and wherein $\sigma$is a positive real number that is between 50 % and 90 % of said minimum value R_2 , wherein $\gamma$is in particular at least 60 % or 65 % of said minimum value R_2, wherein $\gamma$is in particular at most 80 % or 75 % of said minimum value R_2 , whereinγ $\gamma$is more in particular approximately R_2 70 % of said minimum value R_2.

[0062] The inventors generally established that the shape of the guide wall 52 in the outer regions (i.e. radially beyond the inflection line) is important for the air flow in positive input ventilation, while the shape of the guide wall 52 in the centre (i.e. radially within the inflection line) is important for the air flow in extraction.

[0063] The valve device 40 according to the present invention is configured to have, in positive input ventilation and in the maximum open position of the airflow guide 50, a nominal flow rate between 50 m^3 per hour and 100 m^3 per hour, which nominal flow rate is in particular at least 60 m^3 per hour or 70 m^3 per hour, which nominal flow rate is in particular at most 90 m^3 per hour or 80 m^3 per hour, which nominal flow rate is more in particular approximately 75 m^3 per hour. In extraction, the nominal flow rate is typically higher, in particular because the full 360° circumference of the valve device 40 is used in extraction, while in positive input ventilation (as described in more detail below with reference to Figure 7A) only a part of the full 360° circumference is used.

[0064] Figures 5A and 5B show details about one of the fins 56. It is relevant to note that the shape is symmetrical with respect to a central plane that comprises the central axis 68. In other words, the design is symmetrical with respect to a plane in the radial direction such that there is as little influence as possible on the air flow, both in positive input ventilation and extraction. Due to the bi-directional air flow, a droplet-shaped cross-section is less efficient. In an embodiment, the cross-section of a fin 56 is a two-dimensional Sears-Haack body.

[0065] Figures 7A and 7B show results of numerical simulations of the air flow in positive input ventilation through a known valve device. The air flow is shown via vector arrows, wherein the length and concentration of the vectors are indicative of the speed (i.e. the longer the arrow and/or the more arrows per unit area, the higher the speed).

[0066] The valve device is placed in a ceiling 84 and is coupled to a cylindrical pipe 82. This pipe 82 is in turn typically coupled via a 90° connection to a flat pipe 80 that runs through the ceiling. The effect of this corner connection is that, in positive input ventilation, the airflow is mainly concentrated on one side of the valve device. This is evident in Figure 7A where the left side of pipe 82 experiences almost no flow. The known valve device comprises a cylindrical tubular element 44 (i.e. with a constant radius) coupled to a flange-shaped element 46. The inner wall therefore forms an acute angle of 90°. The flange-shaped element 46 does not have a smooth shape as there is a transition from a flat portion to an inclined portion. Based on the simulation results, it appears that there is a pressure drop across the valve device in positive input ventilation of approximately 15 Pa at a flow rate of 75 m^3/h. In addition, there is also an acceleration of the airflow near the exit of the valve device as visible in the accumulation of vectors, this acceleration will normally lead to noise. This acceleration is more visible in the detail in Figure 7B.

[0067] Figures 8A to 8E show results of numerical simulations of the air flow in positive input ventilation through a valve device according to the present invention. Figures 8A, 8B and 8E illustrate a different design of the guide wall 52. Figures 8B and 8C illustrate a different design of the inner wall 66. Figures 8C and 8D illustrate a different position of the airflow guide 50 relative to the base body 42.

[0068] Figures 8A to 8E illustrate that the smooth shape of the inner wall 66 ensures a concentration of the air flow to the airflow guide 50. In this way, a narrowest zone of the air flow approaches more the inside of the valve device compared to the known valve device. Accelerating the air flow near the exit of the valve device is therefore avoided. The Figures also illustrate this as the amount/length of the vector arrows is almost the same near the exit.

[0069] In addition, the top of the airflow guide 50 is always located above the narrowest zone of the base body 42. The inventors have determined that, if the top is lower than the narrowest zone, the pressure drop across the valve device increases significantly. Based on the simulation results, it appears that there is a pressure drop across the various valve devices in positive input ventilation of approximately 6 Pa or 7 Pa at a flow rate of 75 m^3/h. In contrast, a crest below the narrowest zone gave rise to a pressure drop of 10 Pa or 11 Pa at a flow rate of 75 m^3/h.

[0070] Figures 8A to 8E further illustrate that the walls 52, 66 along which airflow passes, are ideally as smooth as possible. Any indentation, deviation, angle, etc. typically results in a separation of the airflow from the respective surface. In turn, this often resulted in the formation of vortices and/or turbulence.

[0071] In positive input ventilation, the inventors further determined that an outer part of the design of the airflow guide 50 in combination with the narrowed inner wall 66, e.g. the mutual alignment, smoothness, similar outer radius, etc. is important for a desired air flow. The specific design of the top of the airflow guide 50 was less relevant as long as it was high enough compared to the constriction.

[0072] Figures 9A and 9B show the valve device of Figure 8C for use in extraction. The air flow illustrates a dead zone (i.e. a low flow zone) at the top and side of the airflow guide 50. This shows that the air flow actually separates from the airflow guide 50 before it passes the top thereof. As already described above, this separation of the air flow is undesirable.

[0073] Figure 9C shows a valve device with a modified airflow guide 50. Mainly the design of the top of the airflow guide 50 has been modified by placing the inflection line higher, compared to the constriction as well as giving it a larger radius such that it is radially closer to the constriction. The simulation illustrates that the airflow sticks to the airflow guide 50 until it approaches the top.

[0074] Although certain aspects of the present invention have been described with respect to specific embodiments, it is apparent that these aspects may be implemented in other forms within the scope of the claims.

Claims

1. A valve device (40) for use in a ventilation system, wherein the valve device comprises:

- a base (42), configured to be placed in an opening in a wall, in particular a ceiling, of a space, which base is provided with:

  - a first circular opening (44a), configured for connection to a pipe of the ventilation system;
  - a second circular opening (46b), located opposite the first circular opening; and
  - an inner wall (66), extending between the circular openings, which inner wall is substantially rotationally symmetrical with respect to a central axis (68),

  wherein a distance between the inner wall and the central axis measured perpendicular to the central axis:

    - has a first value (R_1) at the first circular opening;
    - has a maximum value (R_3) at the second circular opening; en
    - has a minimum value (R_2) at an intermediate location (h_2) between the circular openings, which first value is greater than the minimum value and smaller than the maximum value, wherein said distance between the inner wall and the central axis, measured perpendicular to the central axis, monotonically decreases from the first value to the minimum value and monotonically increases from the minimum value to the maximum value; and
    - an airflow guide (50), mounted on the base, which airflow guide comprises a guide wall (52) facing the base, which guide wall is substantially rotationally symmetrical with respect to said central axis, wherein a cross-section through the guide wall in a plane comprising the central axis follows a substantially bell-shaped curve, wherein a central part of the guide wall is closer to the first circular opening than an outer part of the guide wall and wherein a hypothetical disk (5), perpendicular to the central

axis with said minimum value as a radius, positioned at said intermediate place, intersects the guide wall in an intersection line (74), **characterized in that said** bell-shaped curve is substantially parallel to said inner wall for an outer part of the guide wall.

2. The valve device according to claim 1, **characterized in that** a cross-section through the inner wall in said plane follows a substantially smooth curve.

3. The valve device according to claim 1 or 2, **characterized in that** said distance between the inner wall and the central axis, measured perpendicular to the central axis, strictly monotonically decreases from the first value to the minimum value and strictly monotonically increases from the minimum value to the maximum value.

4. The valve device according to any one of the preceding claims, **characterized in that** the guide wall of the airflow guide has a maximum radius that is substantially the same as said maximum value.

5. The valve device according to any one of the preceding claims, **characterized in that** said outer part of the guide wall comprises at least the part of the guide wall that is located at a distance from the central axis, measured perpendicular to the central axis, which distance is greater than 90%, in particular 80% and more in particular 75%, of said maximum value.

6. The valve device according to any one of the preceding claims, **characterized in that** the guide wall at its end forms an angle (α) with respect to a perpendicular plane to the central axis, which angle is between 5° and 35°, which angle is in particular at least 10° or 13°, which angle is in particular at most 30° or 25°, which angle is more in particular approximately 15°.

7. The valve device according to any one of the preceding claims, **characterized in that** said intersection line is circular with a radius (R_S) that is between 10% and 50% of said first value, which radius is in particular at least 20% or 25% of said first value, which radius is in particular at most 40% or 35% of said first value, which radius is more in particular approximately 30% of said first value.

8. The valve device according to any one of the preceding claims, **characterized in that** said substantially bell-shaped curve comprises an inflection point (76) on either side of the central axis, which inflection points together form an inflection line of the guide wall, wherein:

   - said inflection line is located near said intersection line; or
   - said inflection line is located closer to the first circular opening than said intersection line.

9. The valve device according to any one of the preceding claims, **characterized in that** said substantially bell-shaped curve is described by a Gaussian function or a Cauchy function or a linear combination thereof:

$$y = \left(e^{-\frac{1}{2}\left(\frac{x}{\sigma}\right)^2}\right) * w_G + \left(\frac{1}{1 + \left({}^{x}/_{\gamma}\right)^2}\right) * w_C$$

   wherein x is the distance from the central axis, measured perpendicular to the central axis, $y$describes the distance along the central axis, σ is the standard deviation of the Gaussian function, γ is the scale parameter for the half-width of the Cauchy function, and w_G and w_C are weight parameters of the linear combination, wherein, preferably:

   - w_G and w_C are each a positive real number whose sum is approximately equal to a height of the guide wall, measured along the central axis;
   - σ is a positive real number that is between 20% and 60% of said minimum value, wherein σ is in particular at least 30% or 35% of said minimum value, wherein σ is in particular at most 50% or 45% of said minimum value, wherein σ is in particular approximately 40% of said minimum value; and
   - γ is a positive real number that is between 50% and 90% of said minimum value, wherein γ is in particular at least 60% or 65% of said minimum value, wherein γ is in particular at most 80% or 75% of said minimum value, wherein γ is in particular approximately 70% of said minimum value.

10. The valve device according to any one of the preceding claims, **characterized in that** said minimum value is between 60% and 95% of said first value, which minimum value is in particular at least 70% or 75% or 80% of said first value, which minimum value is in particular at most 90% or 85% of said first value, which minimum value is more in particular approximately 82% or 83% of said first value.

11. The valve device according to any one of the preceding claims, **characterized in that** the valve device further comprises a support (54) that is fixedly attached to the base, wherein the guide wall is slidably attached to the support.

12. The valve device according to claim 11, **characterized in that** the support is fixedly attached to the base by means of a number of fins (56) protruding through the guide wall, which fins have a smooth surface.

13. A ventilation system for a building (1) comprising at least one space (12, 14, 16), the ventilation system comprising:

- a ventilation unit (10);
- a network of pipes (24, 26, 28, 30, 32) connected to the ventilation unit; and
- a valve device (40) placed in a wall, in particular a ceiling, of said at least one space and connected to a pipe of said network of pipes,

characterized in that the valve device is a valve device according to any one of the preceding claims.

14. The ventilation system according to claim 13, **characterized in that** the ventilation system has a blowing state and an extraction state, wherein, in the blowing state, the ventilation system is configured to blow air through the valve device to said at least one space and wherein, in the extraction state, the ventilation system is configured to extract air through the valve device from said at least one space.

15. The ventilation system according to claim 14, **characterized in that** the ventilation system is configured to blow air through the valve device to said at least one space with a nominal flow rate, which nominal flow rate is between 50 m^3 per hour and 1 m^3 per hour, which nominal flow rate is in particular at least 60 m^3 per hour or 70 m^3 per hour, which nominal flow rate is in particular at most 90 m^3 per hour or 80 m^3 per hour, which nominal flow rate is more in particular approximately 75 m^3 per hour.

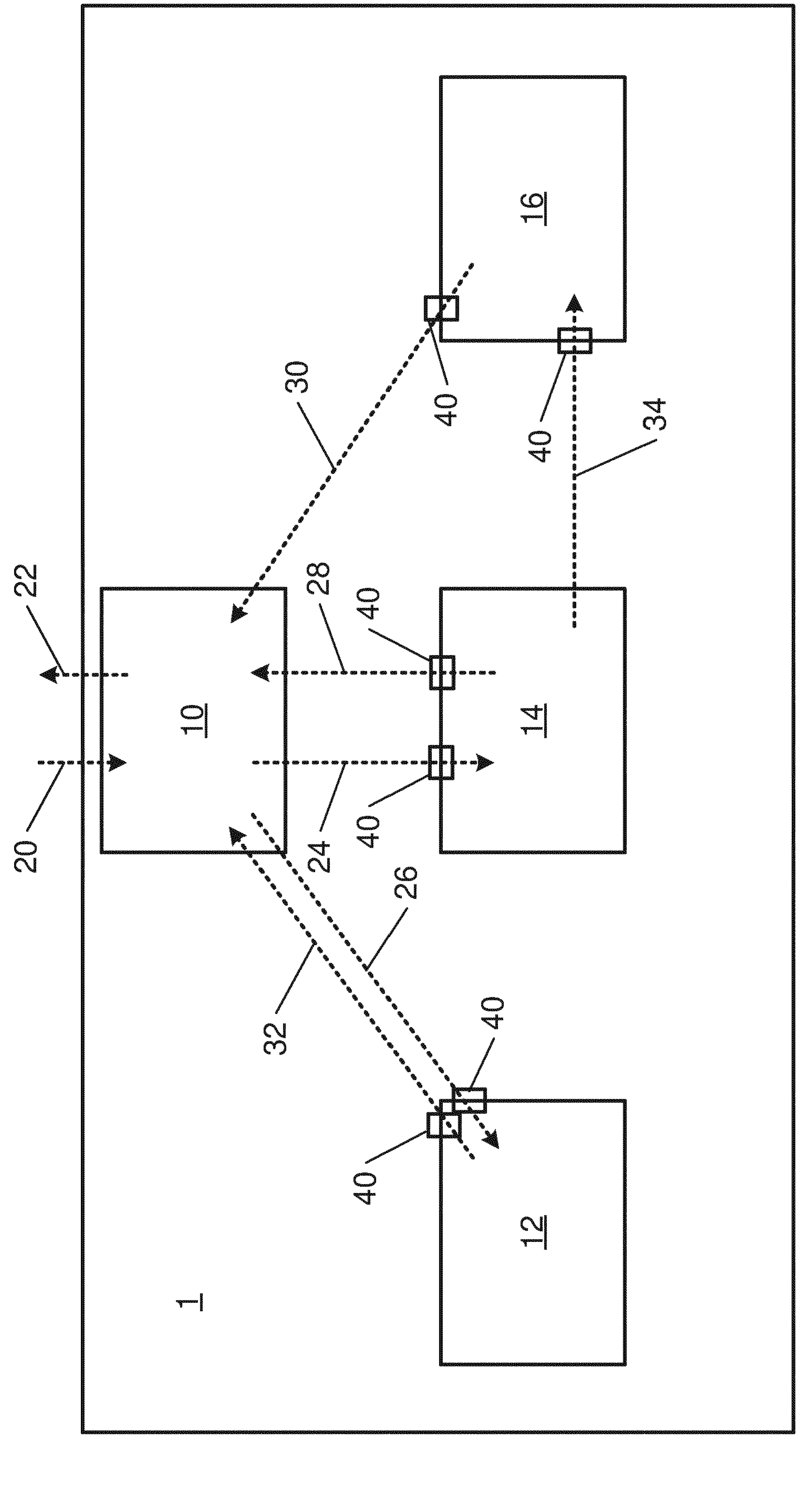
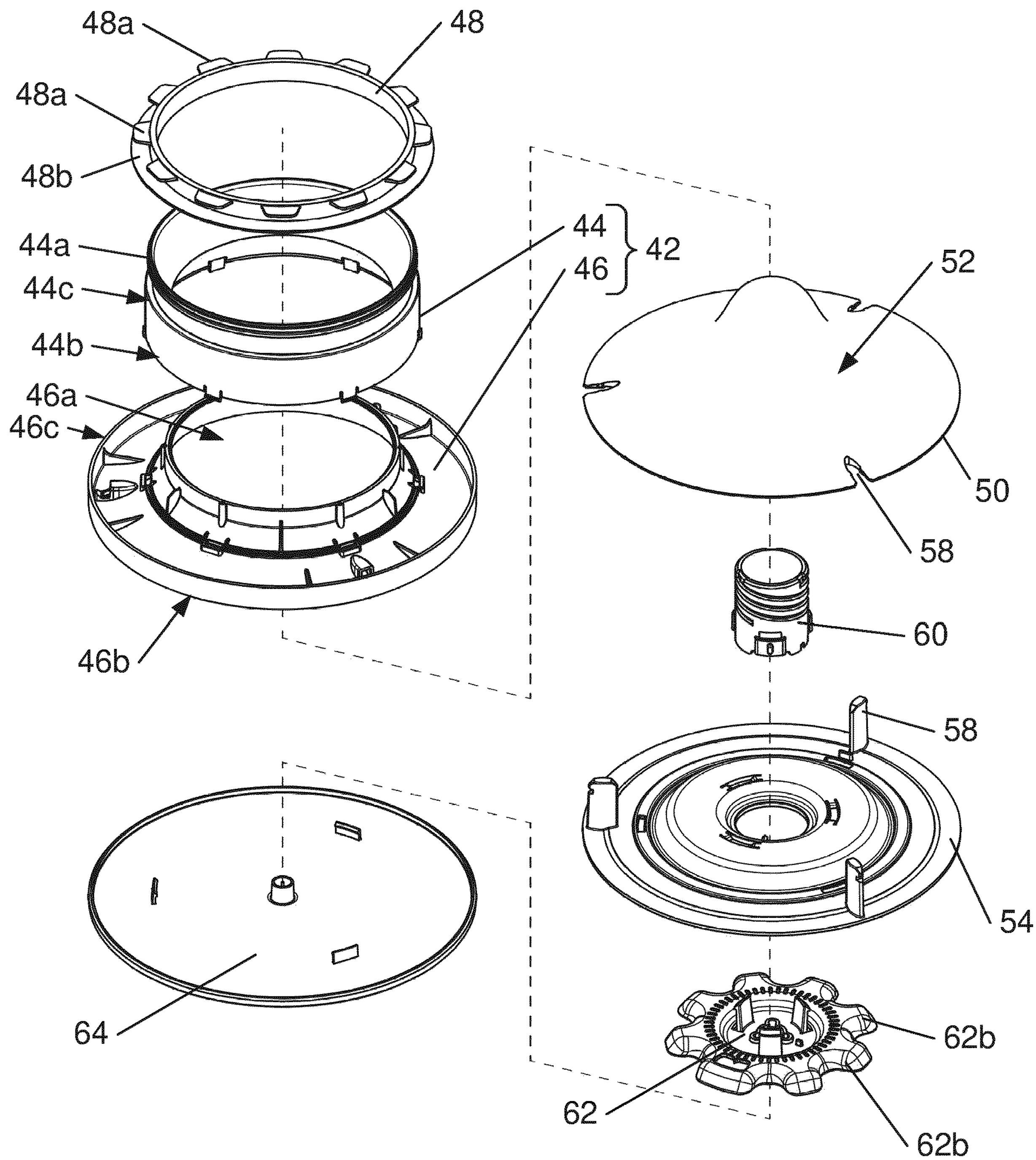


Fig. 1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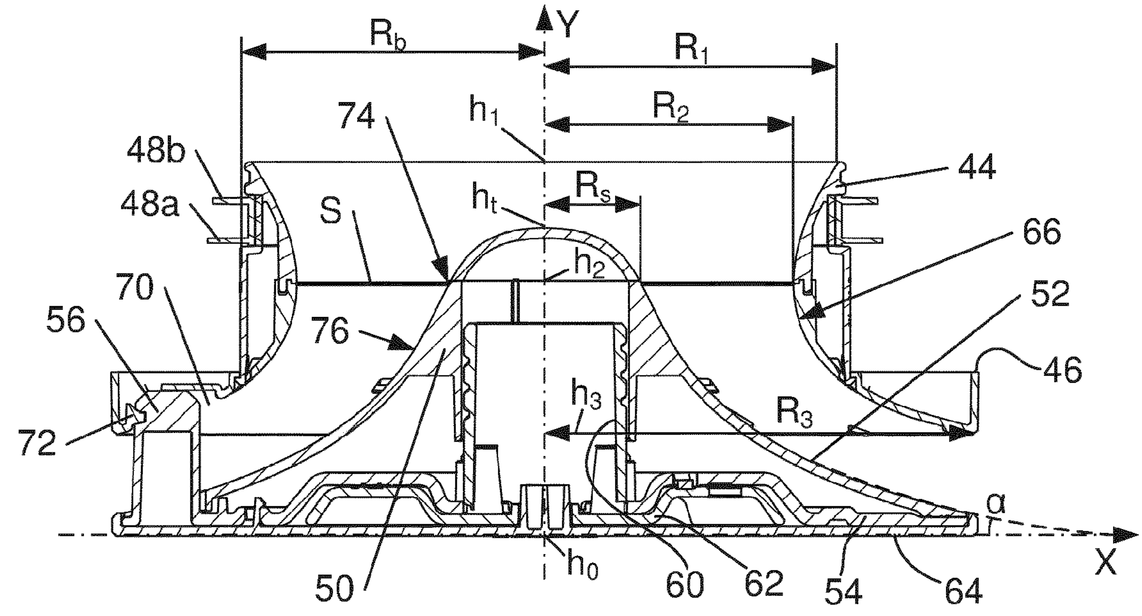
62
62b

Fig. 2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h3
R3
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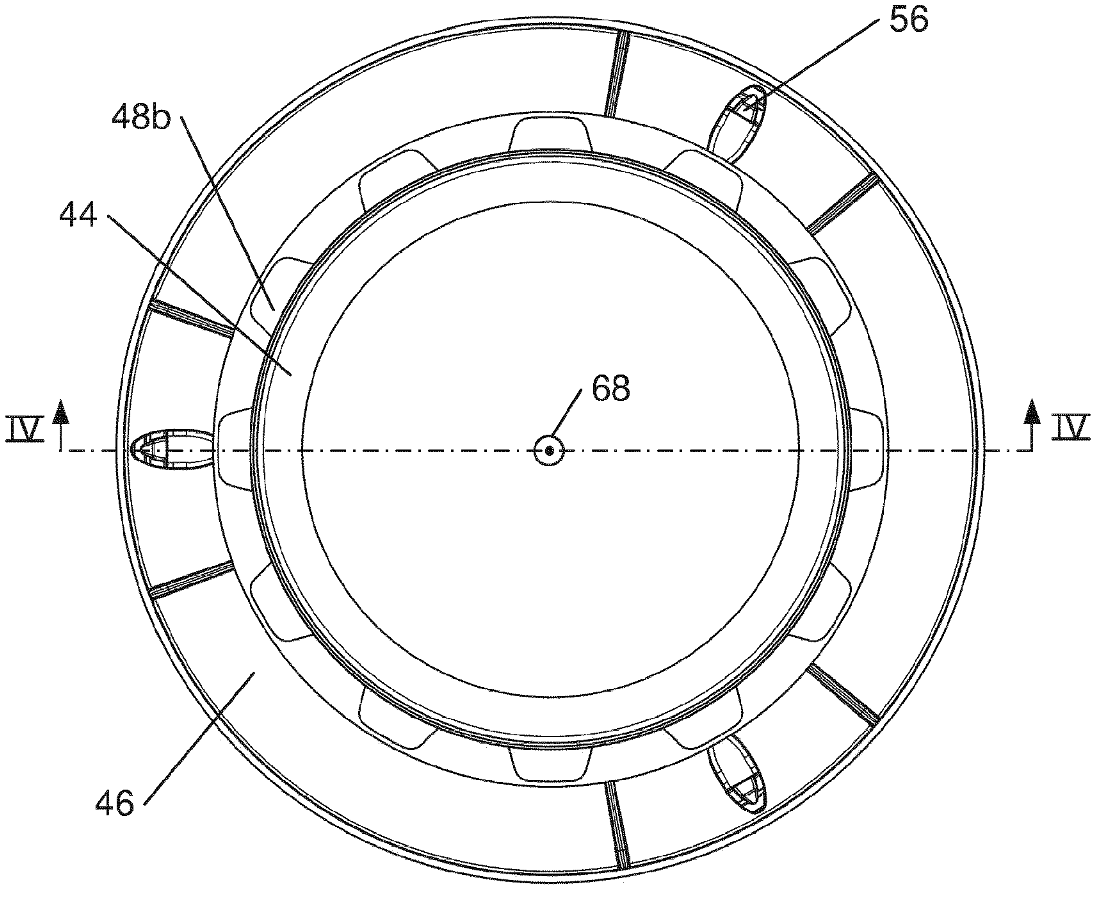
54
64

Fig.4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68
IV
IV
46

Fig.3

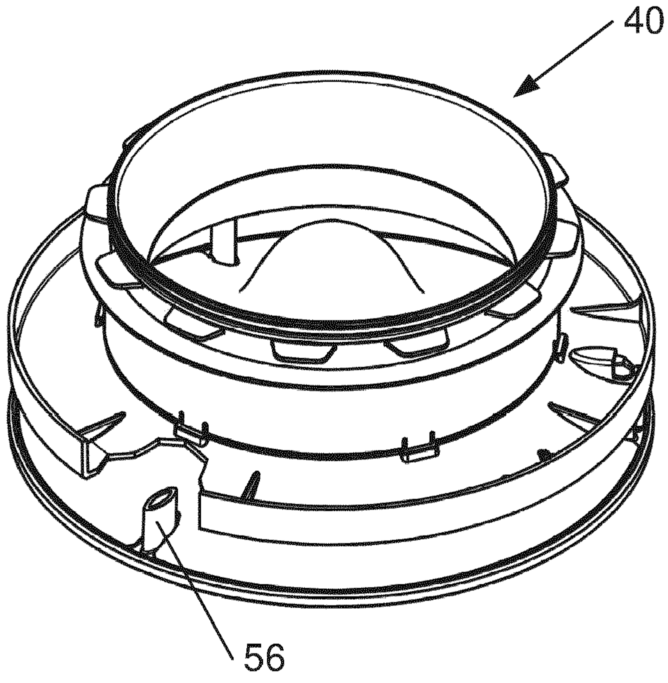

Fig.5A

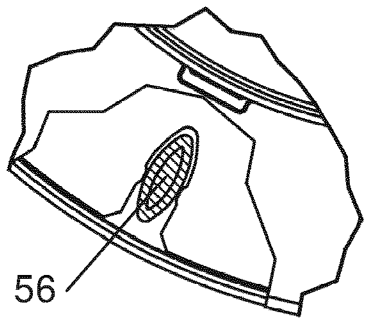

Fig.5B

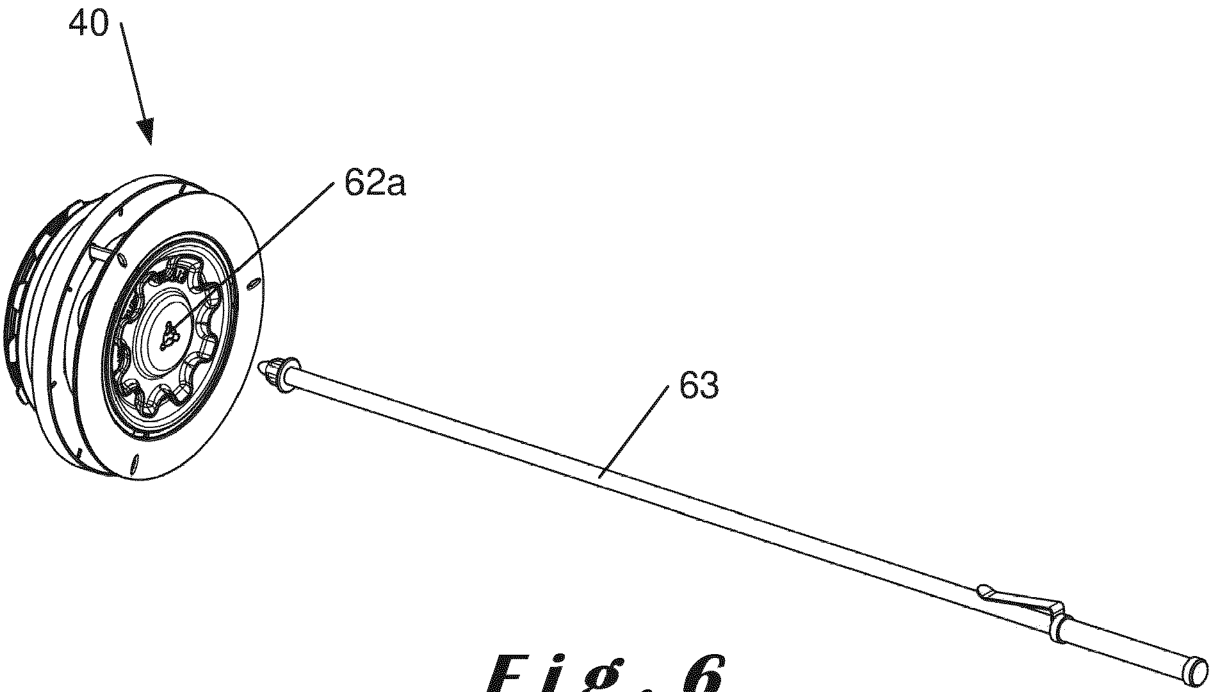

Fig.6

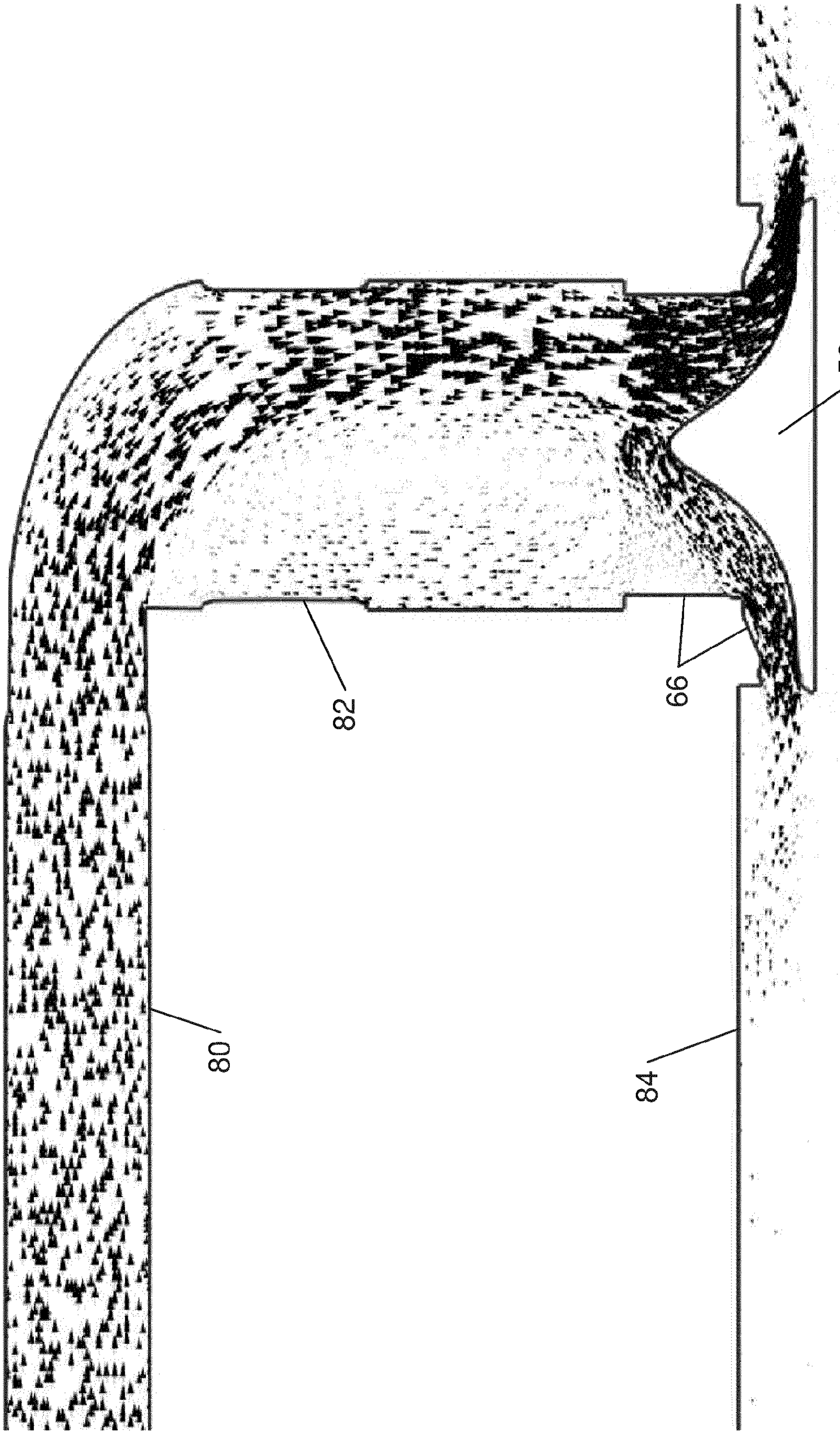

Fig. 7A

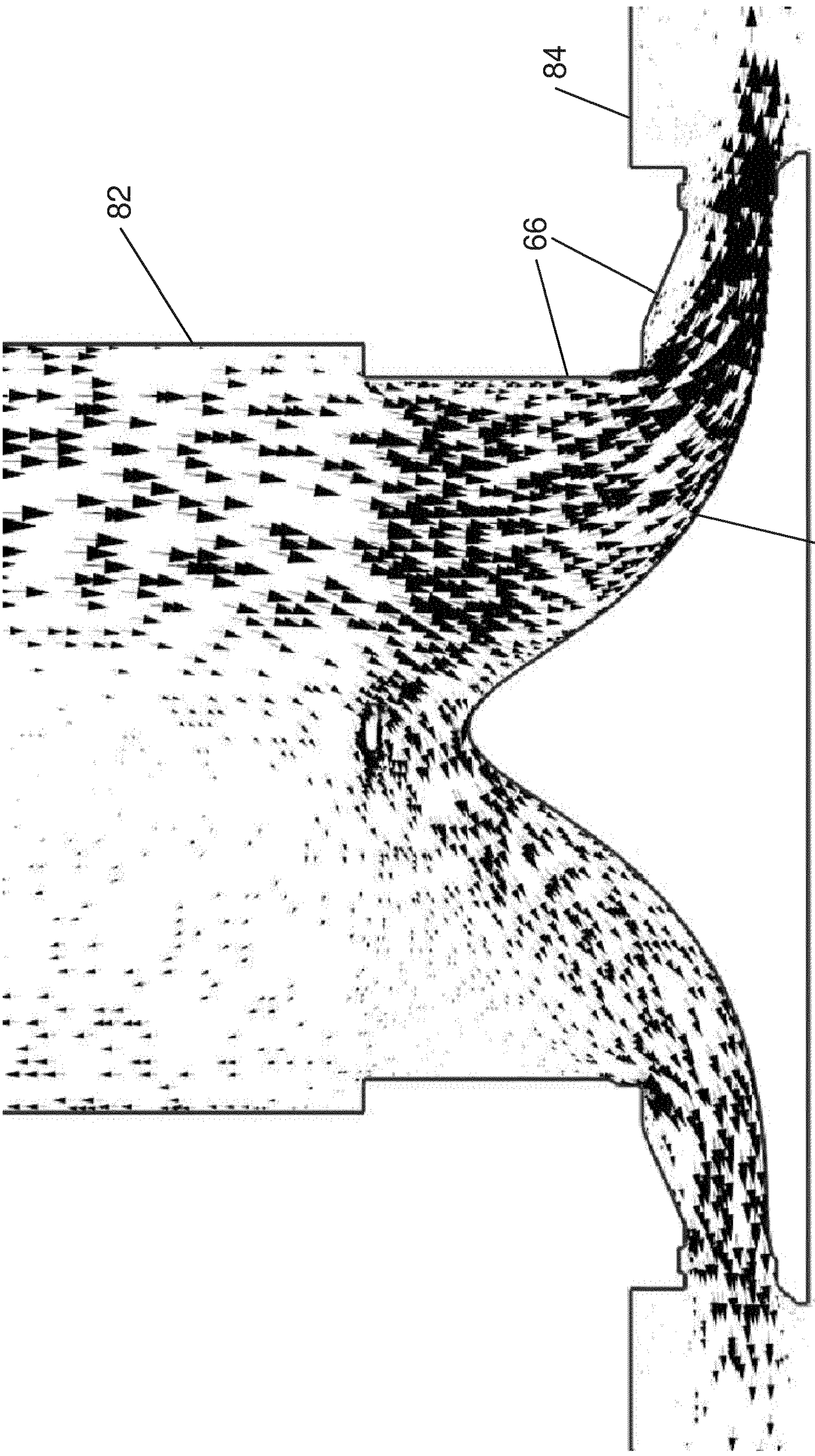

Fig. 7B

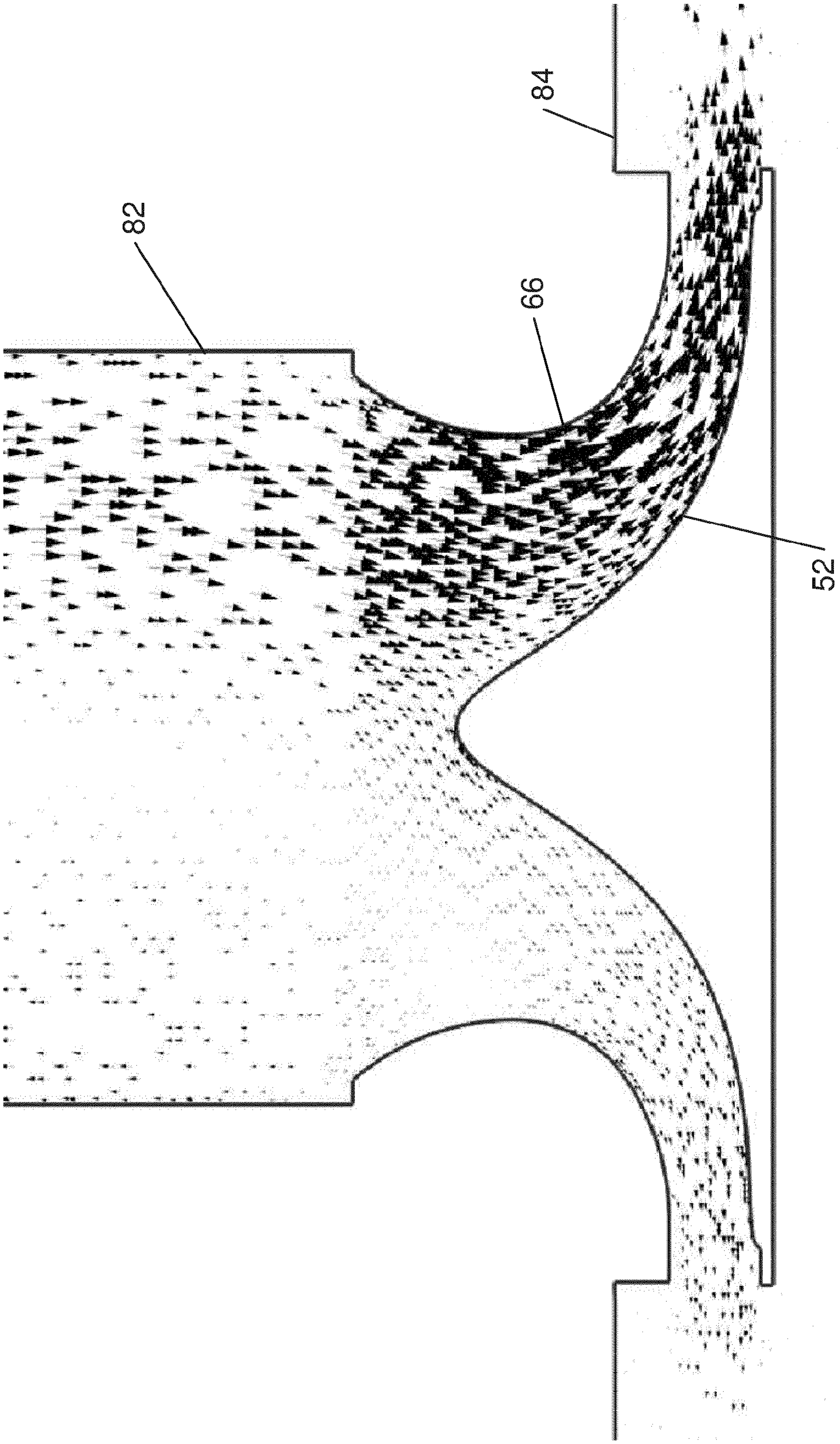

Fig. 8A

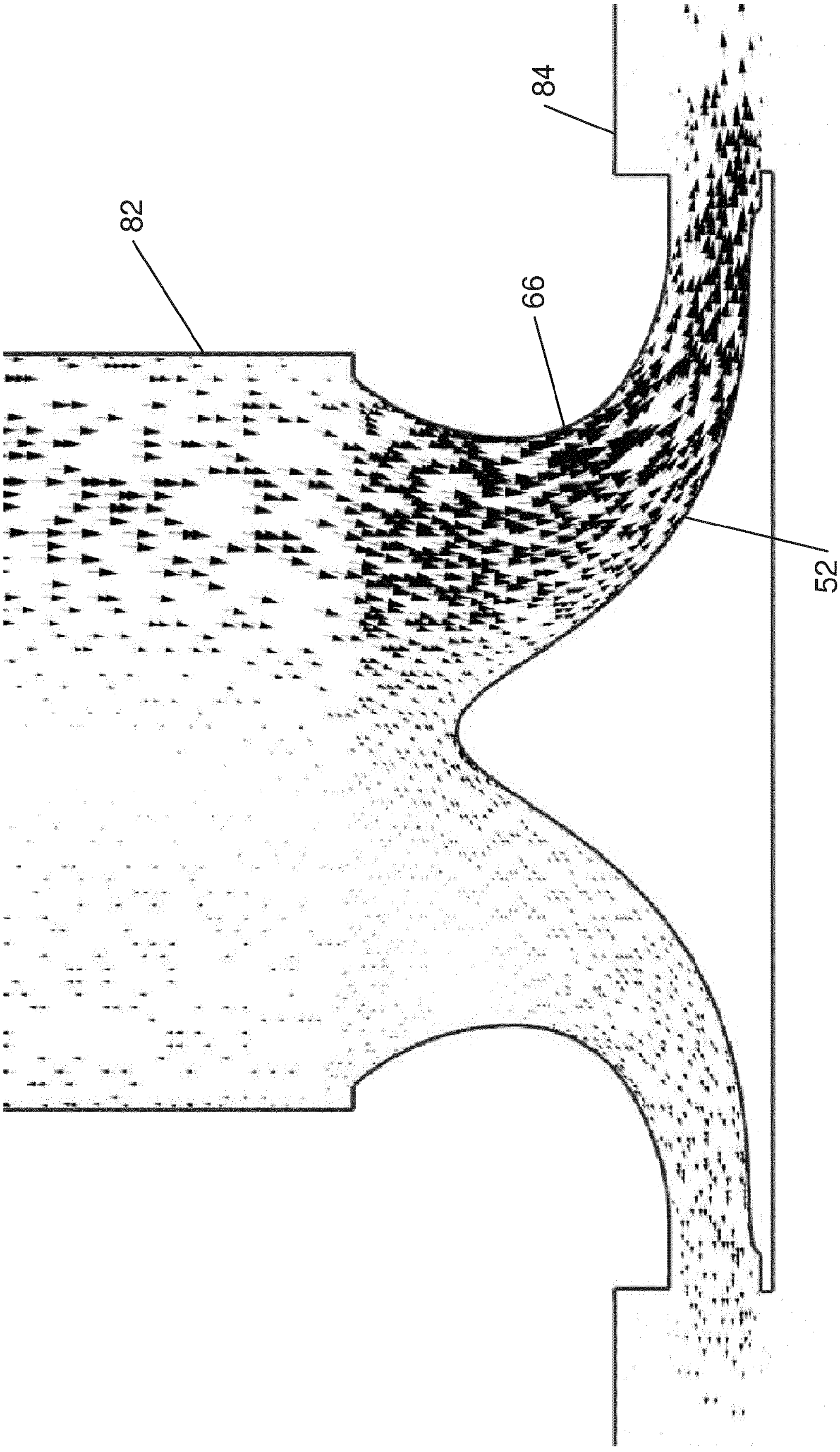

Fig. 8B

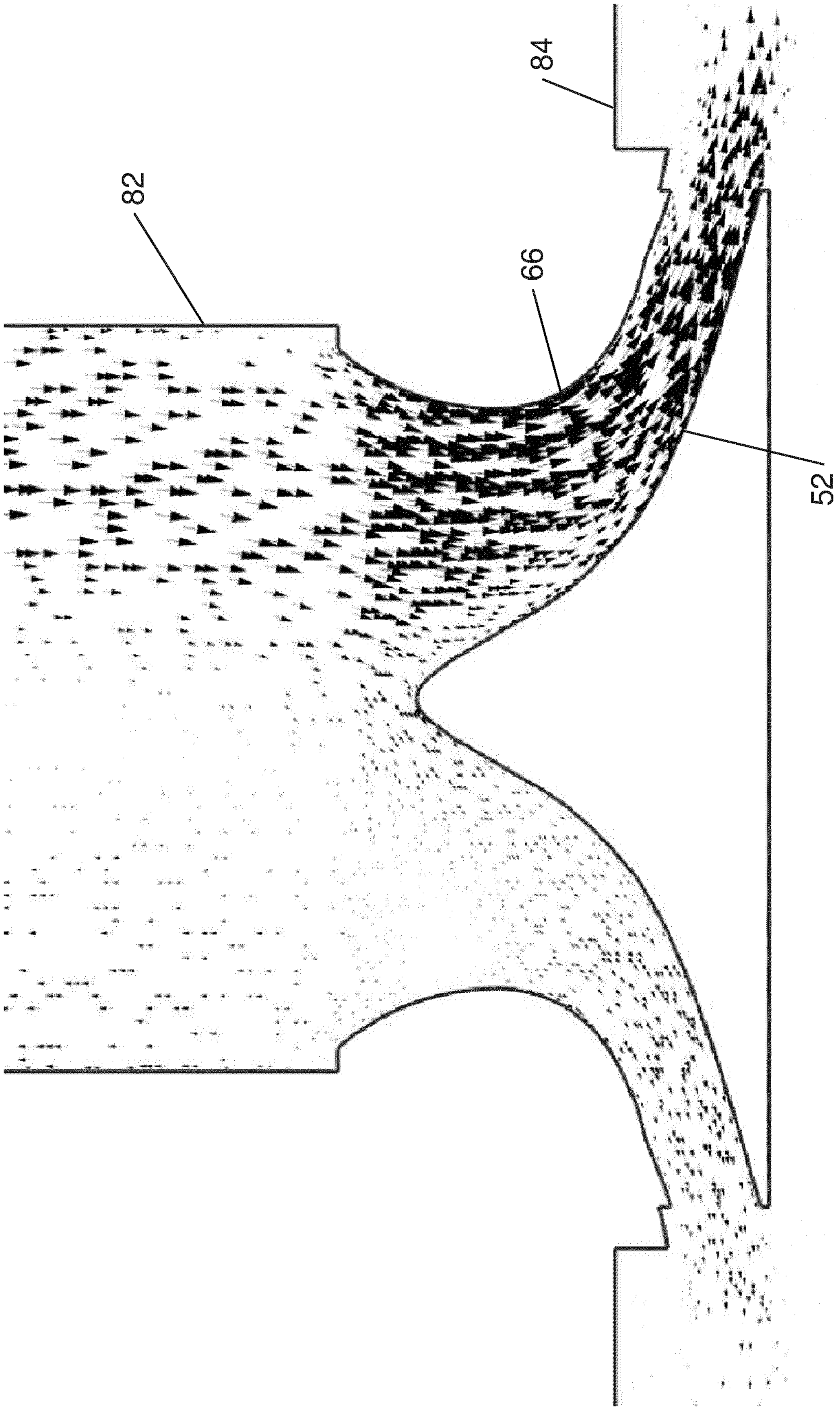

Fig. 8C

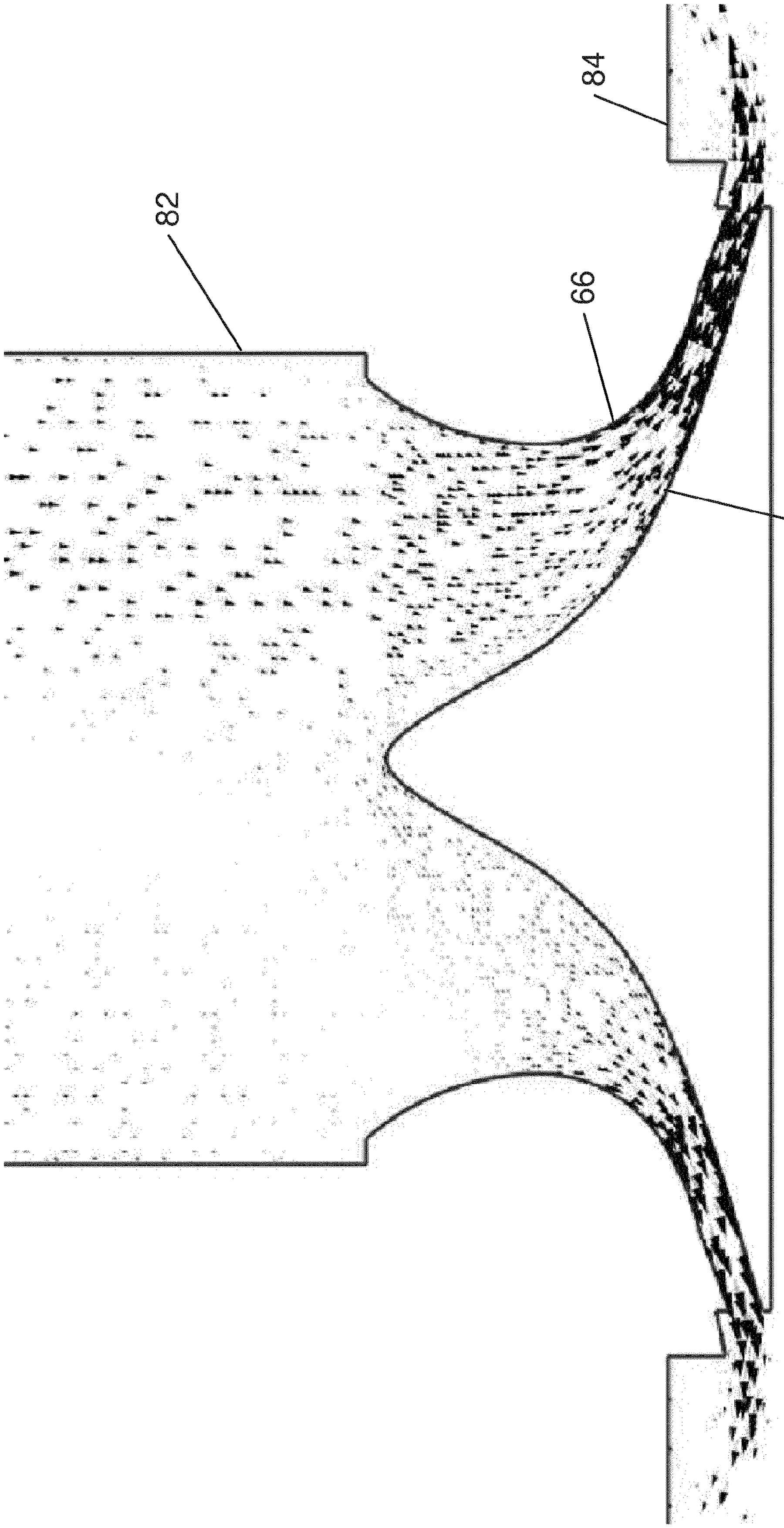

Fig. 8D

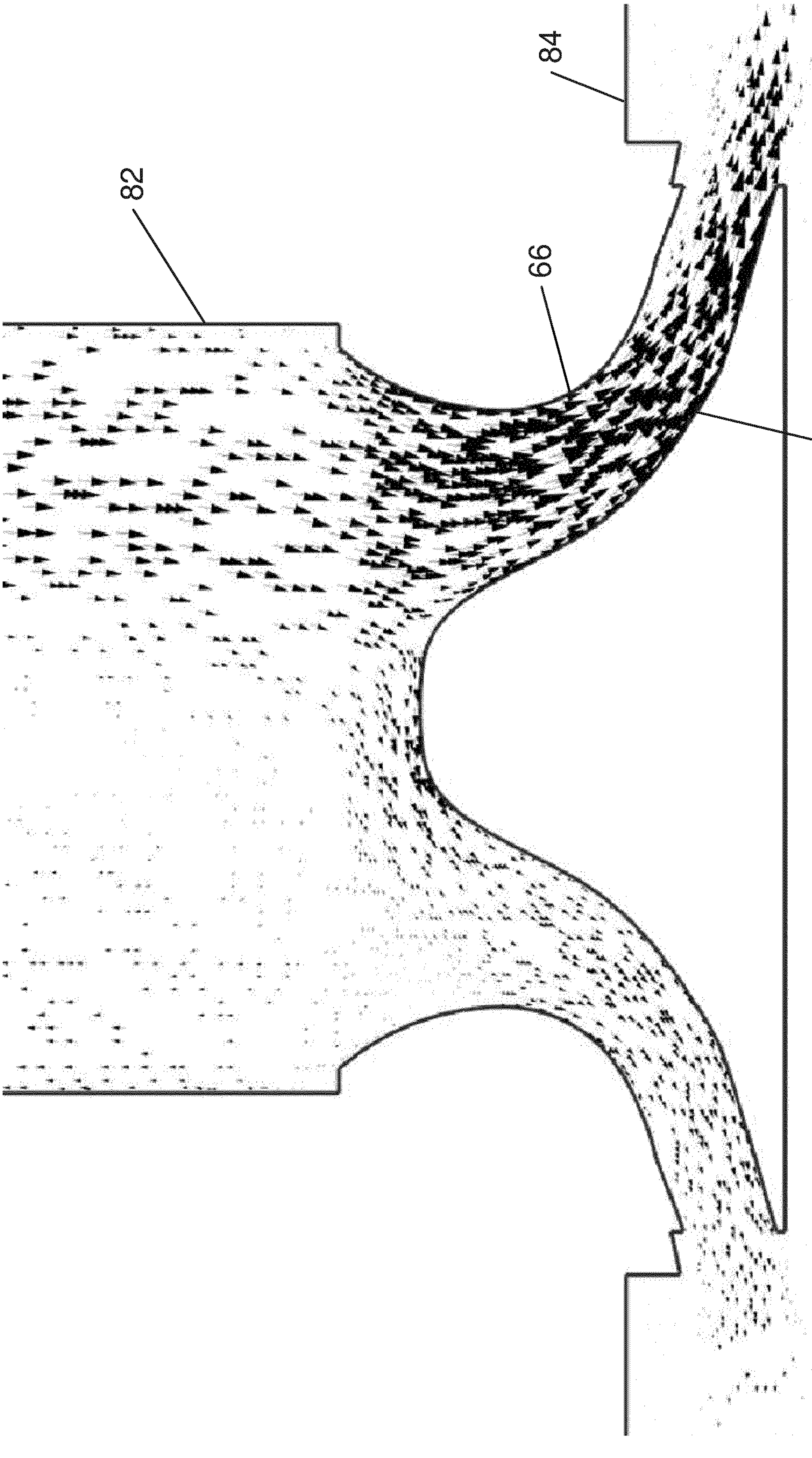

Fig. 8E

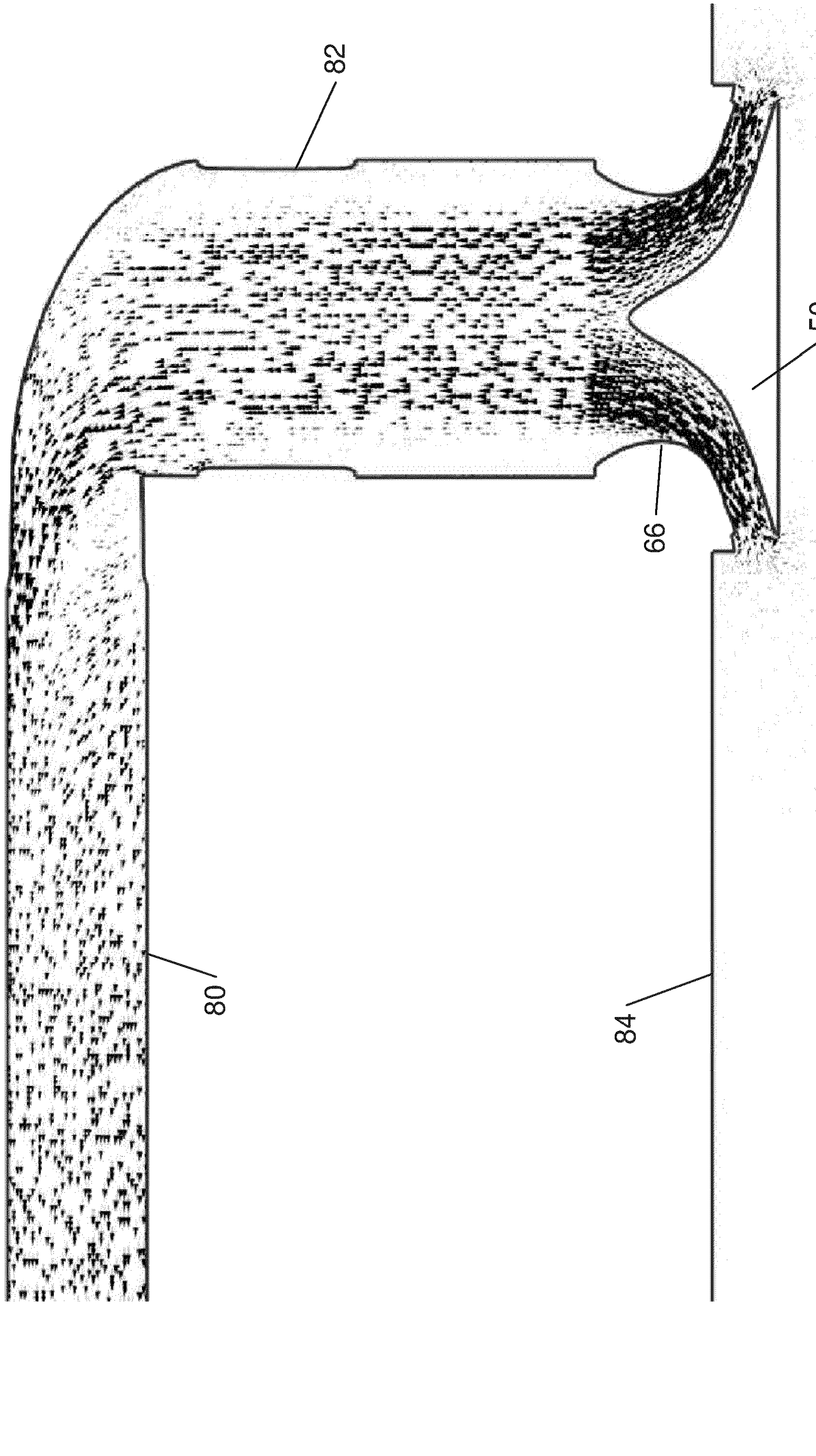

Fig. 9A

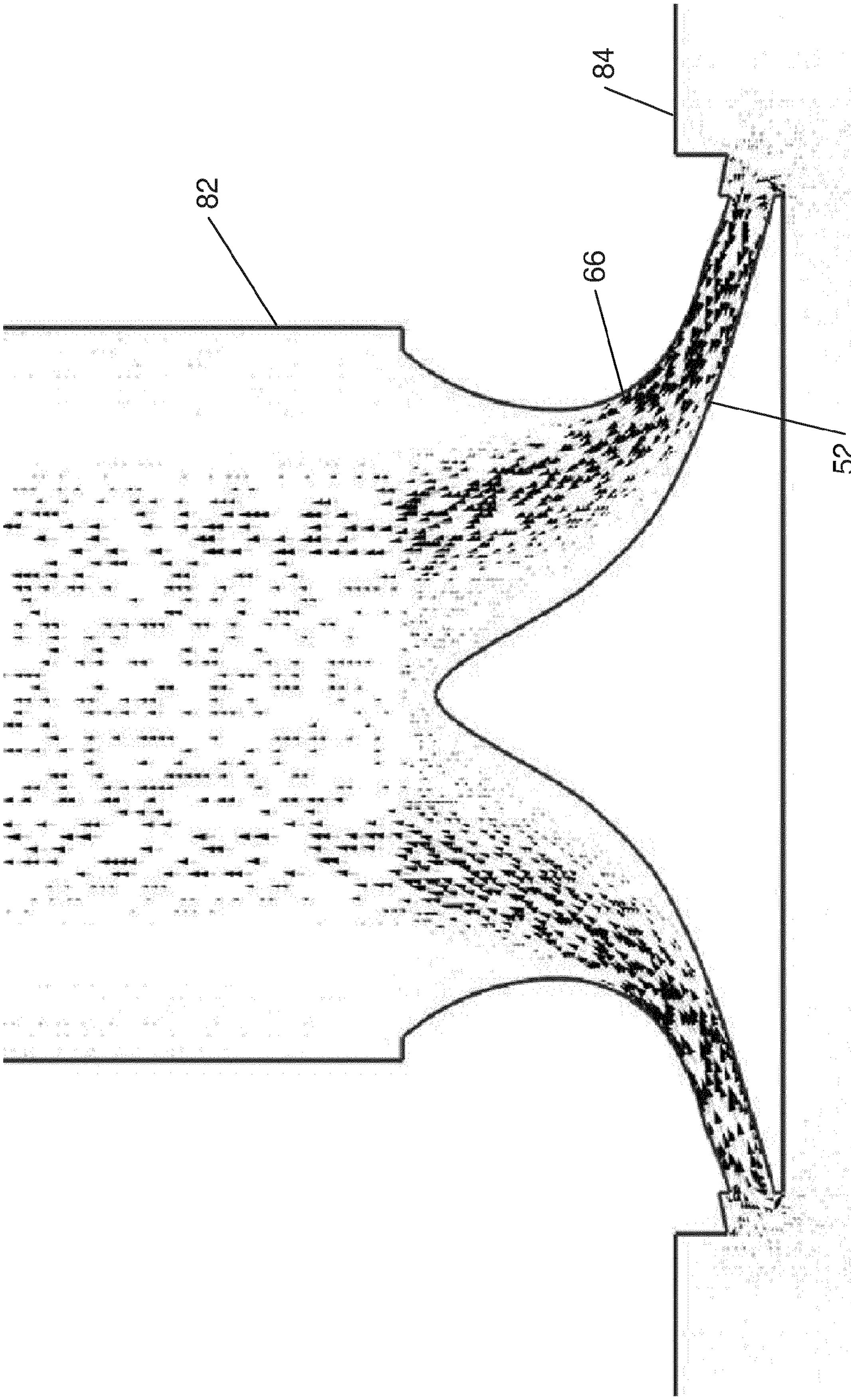

Fig. 9B

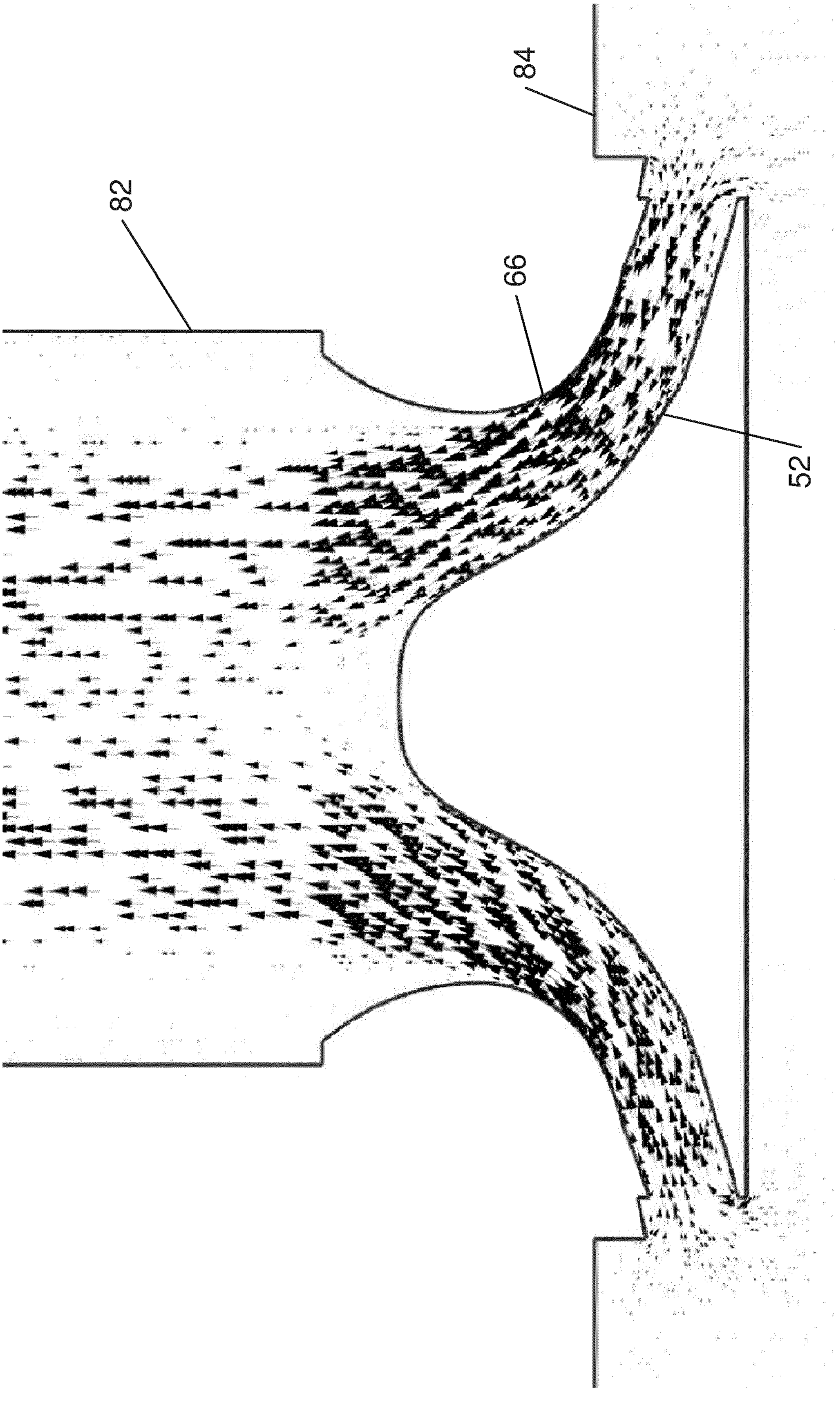

Fig. 9C

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EUROPEAN SEARCH REPORT

Application Number
EP 23 21 7642

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	WO 2022/243351 A1 (PRADO EUROPE BV [BE]) 24 November 2022 (2022-11-24) * the whole document * -----	1-10, 13-15 11,12	INV. F24F13/062
X	KR 200 322 908 Y1 (NA) 14 August 2003 (2003-08-14) * abstract; figures * -----	1	
Y,D	EP 3 575 702 A1 (VENTILAIR GROUP NEDERLAND B V [NL]) 4 December 2019 (2019-12-04) * abstract; figures * -----	11,12	
A	KR 101 959 745 B1 (WON JUN HO [KR]) 4 July 2019 (2019-07-04) * paragraph [0009] - paragraph [0036] * * figures * -----	1	
A	KR 200 474 174 Y1 (WON J H) 27 August 2014 (2014-08-27) * paragraph [0001] - paragraph [0035] * * figures * -----	1	TECHNICAL FIELDS SEARCHED (IPC) F24F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	7 March 2024	Mattias Grenbäck

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07-03-2024

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