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

(11) **EP 2 314 880 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
09.01.2013 Bulletin 2013/02

(21) Application number: **08791016.2**

(22) Date of filing: **10.07.2008**

(51) Int Cl.:
F04D 29/42 *(2006.01)* ***F04D 29/66*** *(2006.01)*

(86) International application number:
PCT/JP2008/062442

(87) International publication number:
WO 2010/004628 (14.01.2010 Gazette 2010/02)

(54) SIROCCO FAN AND AIR CONDITIONER USING THE SAME

SIROCCO-LÜFTER UND DIESEN VERWENDENDE KLIMAANLAGE

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(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR

(43) Date of publication of application:
27.04.2011 Bulletin 2011/17

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Description

Technical Field

[0001] The present invention relates to a method of designing a sirocco fan, a sirocco fan and an air-conditioning apparatus using the same, and more specifically to a sirocco fan (and a method for designing this fan) that is configured to reduce a generated noise and an air-conditioning apparatus using the same.

Background Art

[0002] In EP 1 703 138 A2, a blower includes a multiblade fan (3) and a scroll casing (4) accommodating the multiblade fan (3) therein. The scroll casing (4) has two side walls (13) opposed to each other, a curved peripheral wall (12a, 12b), and a tongue (9) continuous with the curved peripheral wall (12a, 12b). The scroll casing (4) also has an intake opening defined in one of the two opposed side walls (13) and a discharge opening (8) delimited by the two side walls (13), the curved peripheral wall (12a, 12b), and the tongue (9). The curved peripheral wall (12a, 12b) has a first peripheral wall (12a) continuous with the tongue (9) and a second peripheral wall (12b) formed on a downstream side of the first peripheral wall (12a) with respect to the direction of travel of air so as to be continuous with the first peripheral wall (12a).; The first peripheral wall (12a) is concentric with the multiblade fan (3) and has a constant radius of curvature, while the second peripheral wall (12b) has an expansion angle such that a distance (L) between a center (11) of the multiblade fan (3) and the second peripheral wall (12b) increases towards the discharge opening (8).

[0003] JP 9 126 193 discloses: Counterflowing air blowing back from blades 7 to a suction port 14 of a scroll casing 4 is blown out from the upper surfaces of the blades 7, and substantially no air is sucked in this part under a normal blowing condition. In view of this point, the upper surfaces of the blades 7 in a zone A ranging from an angle of -60deg. to an angle of +60deg. in the rotating direction of a centrifugal impeller about a nose part 18 as an original point, in which counterflow likely occurs, are covered with a wide part 24 of a bell-mouth 15, an opening edge part 26 or the like. The upper surfaces of the blades 7 in a zone B ranging from an angle of +120deg. to an angle of +270deg. in the rotating direction of the centrifugal impeller about the nose part 18 as an original point, in which counterflow can hardly occur, are partly covered therewith, thereby it is possible to restrain occurrence of counterflow in the zone A.

[0004] Hitherto, a sirocco fan having a cylindrical shape, and serving as a multi-blade centrifugal fan capable of blowing out an airstream in a width-wide belt like manner toward an objective area to be air-conditioned exists. This sirocco fan is often utilized for an indoor unit constituting an air-conditioning apparatus, a dehumidifier, an air cleaner, and so forth. Such a sirocco fan is generally constructed by housing a fan in which a plurality of thin long blades are arranged on a circumference and formed to have a cylindrical shape as a whole in a scroll casing where a suction inlet and a blowing-outlet are formed. Further, the sirocco fan is configured to suck in air through the suction inlet into the inside thereof and to blow out the air sucked in from a blowing-outlet side to the area to be air-conditioned.

[0005] As such a sirocco fan, "a multi-blade fan provided with a plurality of multi-blade centrifugal fan units that are coupled along the same rotation axis at a space between each other, and a casing in which the aforementioned coupled plurality of multi-blade centrifugal fan units are housed, wherein the casing forms a flow path for use in a blowing-out operation for blowing out the air that is blown out from the aforementioned plurality of multi-blade centrifugal fan units toward the outside, and which the aforementioned flow path for use in a blowing-out operation serves as a common flow path connecting to the aforementioned plurality of multi-blade centrifugal fan units" is proposed (for example, refer to Patent Document 1).

[0006] [Patent Document 1] Japanese Unexamined Patent Application Publication No. 11-324984 (Page 5, Figs. 7 and 8)

Disclosure of Invention

Problems to be Solved by the Invention

[0007] In the hitherto known multi-blade fan, there has been a problem in which when a loss coefficient of an operating point is small, and the operating point is on an open side in relation to a surging area, a lateral width of the fan is small and a noise generated at a time when a predetermined air volume is produced becomes large. That is, in such a sirocco fan, when the predetermined amount of the blowing-out air volume is supplied to the area to be air-conditioned, a sound generated from the fan becomes large, and this results in a noise. The noise is transmitted to the area to be air-conditioned and this sometimes gives an uncomfortable feeling to a user. Furthermore, there has also been a problem in which when a predetermined noise value is reduced, the blowing-out air volume from the sirocco fan becomes small, and when blowing-out air volume is increased, the noise value becomes large, and therefore it is difficult to appropriately balance the blowing-out air volume and the generation of the sound. Moreover, there has also been a problem, in which when

a fan width is small, and the loss coefficient is small, a fan diameter has to be unnecessarily formed to be large in order to reduce the noise. Further, in a case that such a sirocco fan is used in the air-conditioning apparatus, there has also been a problem, in which if the fan width is small, and when the heat exchanger is located downstream side of the fan, an air velocity distribution in a width direction of a heat exchanger is uneven, a heat-transmitting capability of the heat exchanger is reduced, and electric power consumption of a compressor increases. Furthermore, there has also been a problem in which a relationship between the loss coefficient and the fan width is unclear.

[0008] The present invention is made to solve the aforementioned problems, and an object is to provide a sirocco fan in which a sound generated at a time when a predetermined amount of the blowing-out air volume is supplied is reduced, and an air-conditioning apparatus using the same.

Means for Solving the Problems

[0009] A sirocco fan designed in accordance with the present invention is characterized in including: a scroll casing including a suction inlet for sucking in air, a blowing-outlet for blowing out the air, and an air path from the suction inlet to the blowing-outlet; a fan housed in the scroll casing, for sucking in the air from the suction inlet and blowing out the air from the blowing-outlet by means of rotation-driving; and a bell mouth attached to the suction inlet of the scroll casing, in which the suction inlet is formed on an extension line of a rotation axis of the fan and on both side surfaces of the scroll casing, in which when a ventilation resistance in the air path is defined as P[Pa], an amount of air sucked in from the suction inlet is defined as Q[m^3/min], a width in a direction of a rotation axis of the fan is defined as L[mm], k is defined as a constant, a height of the scroll casing is defined as H = 246k[mm], and P/Q^2 is defined as a loss coefficient ξ[Pa/(m^3/min)^2], the equation: $f(k^4\xi) = 0.34947(k^4\xi)^2 - 1.0554(k^4\xi) + 1.8$ is satisfied, and the inequality: $0.75f(k^4\xi) \leq L/H \leq f(k^4\xi)$ is satisfied within a range of $0.1 \leq k^4\xi \leq 0.4$.

[0010] A sirocco fan designed in accordance with the present invention is characterized in including: a scroll casing including a suction inlet for sucking in air, a blowing-outlet for blowing out the air, and an air path from the suction inlet to the blowing-outlet; a fan housed in the scroll casing, for sucking in the air from the suction inlet and blowing out the air from the blowing-outlet by means of rotation-driving; and a bell mouth attached to the suction inlet of the scroll casing, in which the suction inlet is formed on an extension line of a rotation axis of the fan and on one side surface of the scroll casing, in which when a ventilation resistance in the air path is defined as P[Pa], an amount of air sucked in from the suction inlet is defined as Q[m^3/min], a width in a direction of a rotation axis of the fan is defined as L[mm], k is defined as a constant, a height of the scroll casing is defined as H = 246k[mm], and P/Q^2 is defined as a loss coefficient ξ[Pa/(m^3/min)^2], the equation: $g(k^4\xi) = 1.39788(k^4\xi)^2 - 2.1108(k^4\xi) + 1.8$ is satisfied, and the inequality: $1.5g(k^4\xi) \leq L/H \leq 2g(k^4\xi)$ is satisfied within a range of $0.1 \leq k^4\xi \leq 0.4$.

[0011] Further, an air-conditioning apparatus in accordance with the present invention is characterized in using the sirocco fan being designed as described above.

Advantages

[0012] In accordance with a sirocco fan with respect to the present invention, since a balance of a blowing out air volume of the air and a noise can be achieved by means of only determining a fan width on the basis of a predetermined formula so that an operating point of the fan is within a predetermined range, a sound generated at a time of supplying a predetermined amount of the blowing out air volume can effectively be reduced.

Brief Description of Drawings

[0013]

[Fig. 1] Fig. 1 is a see-through perspective view illustrating an inside of a sirocco fan in a see-through manner with respect to a first embodiment of the present invention.
[Fig. 2] Fig. 2 is a perspective view illustrating an entire shape of a fan.
[Fig. 3] Fig. 3 is a cross-sectional view illustrating a schematic longitudinal cross-sectional construction of the sirocco fan.
[Fig. 4] Fig. 4 is a graph illustrating a P-Q characteristic and a Ks-Q characteristic of the sirocco fan.
[Fig. 5] Fig. 5 is a graph illustrating a relationship between a ratio L_0/H_0 and a loss coefficient ξ_o of the sirocco fan.
[Fig. 6] Fig. 6 is a graph illustrating the P-Q characteristic and the Ks-Q characteristic of the sirocco fan, which passes an operating point A.
[Fig. 7] Fig. 7 is a graph illustrating a relationship between an air volume between blades per each blade of the fan and a position of the blade.
[Fig. 8] Fig. 8 is a schematic cross-sectional view illustrating a longitudinal cross-sectional construction of a bell mouth.

[Fig. 9] Fig. 9 is a perspective view of the sirocco fan illustrating an area α of the bell mouth.
[Fig. 10] Fig. 10 is an enlarged view of a part of the area a illustrating an rms value of a static pressure fluctuation on a wall surface of the part of the area α when a step is not provided.
[Fig. 11] Fig. 11 is the enlarged view of the part of the area α illustrating the rms value of the static pressure fluctuation on the wall surface of the part of the area α when the step is provided.
[Fig. 12] Fig. 12 is a longitudinal cross-sectional view illustrating a schematic cross-sectional construction of the sirocco fan.
[Fig. 13] Fig. 13 is a see-through perspective view illustrating the sirocco fan in the see-through manner.
[Fig. 14] Fig. 14 is a graph illustrating a P-Q characteristic of the sirocco fan in a case of passing the operating point B.
[Fig. 15] Fig. 15 is a plan view illustrating a schematic entire construction of a ceiling suspended indoor unit on which the sirocco fan is mounted.
[Fig. 16] Fig. 16 is a cross-sectional view illustrating a longitudinal cross-sectional construction of the ceiling suspended indoor unit.
[Fig. 17] Fig. 17 is a table showing a noise value in the ceiling suspended indoor unit.
[Fig. 18] Fig. 18 is a schematic constructional view illustrating a schematic construction of an air-conditioning apparatus with respect to a second embodiment of the present invention.

Reference Numerals

[0014] 1: fan, 2: scroll casing, 2a: suction inlet, 2b: blowing-outlet, 2b1: tongue portion, 2c: air path, 3: bell mouth, 4: tongue portion, 5: suction space, 100: sirocco fan, 110: ceiling suspended indoor unit, 150: air-conditioning apparatus, 151: compressor, 152: condensing heat-exchanger, 153: throttling apparatus, 154: evaporating heat-exchanger

Best Modes for Carrying Out the Invention

[0015] Hereinbelow, an embodiment of the present invention will be explained with reference to the drawings.

First Embodiment

[0016] Fig. 1 is a see-through perspective view illustrating an inside of a sirocco fan 100 in a see-through manner with respect to a first embodiment of the present invention. Fig. 2 is a perspective view illustrating an entire shape of a fan 1. Fig. 3 is a cross-sectional view illustrating a schematic longitudinal cross-sectional construction of the sirocco fan 100. An entire construction of the sirocco fan 100 will be explained on the basis of Fig. 1 through Fig. 3. This sirocco fan 100 is the one that is utilized for an indoor unit constituting an air-conditioning apparatus, such as an air-conditioner, a dehumidifier, or the like, and the dehumidifier, an air cleaner, and so forth. Incidentally, including the Fig. 1, there is a case in which a relationship of a size of each of constituent members in the below illustrated drawings is sometimes different from a real one.

[0017] As illustrated in Fig. 1, the sirocco fan 100 is composed of a fan 1, in which a plurality of thin long blades are arranged on a circumference, and which is formed to have a cylindrical shape as a whole, a scroll casing 2 housing the fan 1, in which an air path is formed in an inside thereof, and a bell mouth 3 attached on an extension line of a rotation center (hereinbelow called as a rotation axis, simply) of the fan 1 and to both side surfaces of the scroll casing 2. The fan 1 is provided with a rotation center, and is configured to suck in air and to blow out the air by means of a rotation. The scroll casing 2 is composed of a suction inlet 2a formed to have an opening on a rotation axis, a blowing-outlet 2b that blows out the air that is sucked in from the suction inlet 2a to an objective area, and an air path 2c that is formed to have a scroll casing shape (curved shape) in a rotating circumferential direction of the fan 1, and that allows the suction inlet 2a and the blowing-outlet 2b to communicate with each other.

[0018] The bell mouth 3 is formed to have an opening and is configured to be attached to the suction inlet 2a of the scroll casing 2, and enables the air sucked in from the suction inlet 2a to be intensively accelerated and thereby to be supplied to the fan 1. It is preferable that the fan 1 is constructed such that a fan diameter D is formed as φ= 192mm, for example, a width dimension L is formed to be from 150 to 400mm, for example, and the number of the blades is set to be 40 sheets, for example. It is also preferable that the scroll casing 2 is constructed such that a height H of the scroll casing is formed to be 246mmm. Incidentally, this does not specifically limit a shape of the bell mouth 3, and for example, the shape may be determined corresponding to a length of the fan diameter D.

[0019] Fig. 4 is a graph illustrating a P-Q characteristic and a Ks-Q characteristic of the sirocco fan 100. The P-Q characteristic and the Ks-Q characteristic of the sirocco fan 100 will be explained on the bases of Fig. 4. At this moment, P represents static pressure [Pa], Q represents an air volume [m^3/min], and Ks represents a specific noise [dB], respectively. Further, the specific noise Ks is calculated on the basis of an equation: $Ks = SPL - 10 \cdot \log_{10}(P \cdot Q^{2.5})$. Incidentally, the SPL represents a noise value, and a value, in which a noise generated by the sirocco fan 100 is measured at a

position, spaced apart by about one meter along a rotation axis of the sirocco fan 1, from a center of the bell mouth attached to the suction inlet 2a of the scroll casing 2, is used for the noise value. Furthermore, closed circles in Fig. 4 denote the P-Q characteristic, and open circles denote the Ks-Q characteristic, respectively. Moreover, bracketed numbers (1) through (3) represent the operating points, respectively.

[0020] The P-Q characteristic represents a relationship between the static pressure P (indicated by a scale of a left-side ordinate axis) as a ventilation resistance and the air volume Q (indicated by a scale of a abscissa axis) under a state that a rotation number of the fan 1 is constant. As is denoted by the closed circles in Fig. 4, the smaller, the static pressure is, the easier, the air in the air path 2c becomes to flow, and the larger, the static pressure is, the harder, the air in the air path 2c becomes to flow. That is, at the operating point (3), the air volume becomes to be easily obtained, and at the operating point (1), the air volume becomes to be hardly obtained. Accordingly, it is found that the smaller, the static pressure becomes, the larger the air volume becomes, and the larger the static pressure becomes, the smaller the air volume becomes. Incidentally, in the below explanation, a high static pressure and low air volume side is called as a closure side (upper left side in the graph), and a low static pressure and high air volume side is called as an open side (lower right side in the graph).

[0021] However, even when the air volume becomes small, an area where the static pressure becomes small regionally exists as illustrated in Fig. 4. This area is called as a surging area (an area surrounded by a broken line in Fig. 4). In such a surging area, a flow of air in the air path 2c tends to be unstable. That is, the surging area is an area having a high possibility of causing an abnormal sound due to that the flow of the air becomes unstable. Incidentally, the specific noise Ks (indicated by a scale of a right-side ordinate axis) is configured to increase at the time when the air volume Q increases as denoted by the open circles in Fig. 4. This specific noise Ks is a noise value obtained under consideration for the static pressure P and the air volume Q.

[0022] Fig. 5 is a graph illustrating a relationship between a ratio L_0/H_0 of the sirocco fan 100 and the loss coefficient ξ_0. The relationship between the ratio Lo/Ho of the sirocco fan 100 and the loss coefficient ξ_0 will be explained on the basis of Fig. 5. Fig. 5 illustrates the relationship between the ratio L_0/H_0 and the loss coefficient ξ_0, using a width dimension L_0 in which the specific noise Ks becomes minimum in relation to the loss coefficient $\xi_0 = P_0/Q_0^2$ [Pa/(m^3/min)^2], where the scroll-casing height H_0 is fixed to be 246mm, and the fan width dimension L_0 is varied from 150 to 500mm. In Fig. 5, an ordinate axis represents the ratio L_0/H_0, and an obscissa axis represents the loss coefficient ξ_0 respectively.

[0023] The loss coefficient: $\xi_0 = P_0/Q_0^2$ represents that on the P-Q characteristic illustrated in Fig. 4, the larger the loss coefficient ξ_0 is, the nearer the point on the P-Q characteristic is on the closure side, and the smaller the loss coefficient ξ_0 is, the nearer the point on the P-Q characteristic is on the open side. Incidentally, the loss coefficient is a value obtained by a position of an operating point (P, Q), described later. Further, the ratio L_0/H_0 represents a ratio in a case that the scroll-casing height H_0 is fixed, and the width dimension L_0 is varied. It is found that the width dimension L_0, with which the specific noise Ks becomes minimum, is varied by the loss coefficient ξ_0, from Fig. 5. That is, the nearer the point is on the open side, at which the loss coefficient ξ_0 is small, the longer, the width dimension L_0, in which the specific noise Ks becomes minimum. Accordingly, from Fig. 5, when the loss coefficient ξ is set to be within a range of $0.1 \leq \xi \leq 0.4$, and when the equation: $f(\xi_0) = 0.34947\xi_0^2 - 1.0554\xi_0 + 1.8$, and the equation: $L_0/H_0 = f(\S_0)$ are satisfied, the specific noise Ks becomes minimum. Incidentally, the equation: $f(\xi_0) = 0.34947\xi_0^2 - 1.0554\xi_0 + 1.8$ is a formula that is calculated from the graph illustrated in Fig. 5.

[0024] Next, the reason why the specific noise Ks is varied by the loss coefficient ξ_0 and the width dimension L_0 will be explained.

Fig. 6 is a graph illustrating a P-Q characteristic and a Ks-Q characteristic of the sirocco fan 100, in a case that the same passes an operating point A, while the width dimension L_0 is set to be 230 or 300mm. Further, closed circles denote the P-Q characteristic at the time when the width dimension L_0 is set to be 230mm, and open circles denote the P-Q characteristic at the time when the width dimension L_0 is set to be 300mm, respectively. Furthermore, closed triangles denote the Ks-Q characteristic at the time when the width dimension L_0 is set to be 230mm, and open triangles denote the Ks-Q characteristic at the time when the width dimension L_0 is set to be 300mm, respectively. Incidentally, the operating point explained here is determined in accordance with a designed air volume of a fan unit, and a designed static pressure (a ventilation resistance of a heat exchanger, an air path of the fan unit, a ventilation resistance of the air path of a duct, a ventilation resistance due to a filter or the like).

[0025] In a case that the width dimensions L_0 is set to be 230mm and 300mm, when the P-Q characteristics that pass the operating point A are compared, it is found that the P-Q characteristic of the case of the long width dimension L_0 of 300mm, whose surging area moves toward a lower right (open side) of the graph of the P-Q characteristic is closer to the operating point A than the other. It is found from the P-Q characteristic and the Ks-Q characteristic illustrated in Fig. 6 that the operating point where the specific noise Ks becomes minimum is in the vicinity of the surging area. However, when the operating point is within the surging area or in the vicinity of the surging area, the flow of air becomes unstable, and this results in occurrence of reverse suction or an abnormal sound, and increase of time fluctuation of the air volume. Consequently, in order to form a stable flow of air assuredly, the operating point is required to be closer to the open side in relation to the surging area.

[0026] That is, when a capacity of a fan is increased in relation to a certain operating point (P, Q), a surging area in a P-Q characteristic diagram moves toward a lower right side. At this moment, the more the operating point is spaced apart from the surging area to an open side (i.e., lower right side in the P-Q characteristic diagram), the more the abnormal sound becomes easy to occur. The reason of the cause thereof is because a static pressure fluctuation is increased at a tongue portion (denoted by a reference numeral 2b1 in Fig. 3) of a casing, or in the area where a distance between a bell mouth and a fan is small. In the present invention, occurrence of a noise is configured to be reduced by means of causing the operating point to approach the surging area as much as possible, by increasing the capacity of the fan in relation to the predetermined operating point, and moving the surging area.

[0027] Currently, in order to increase the capacity of the fan, it is considered to increase a fan diameter or a fan width. However, when the fan diameter is increased, a height of a fan unit is unnecessarily increased. In the present invention, a fan unit, which is capable of constructing a fan width to be larger than the hitherto known ones without unnecessarily increasing a height of the fan unit, has a less installation restriction to optimize a relationship between an operating point and a surging area, and can reduces a noise, can be obtained.

[0028] Fig. 7 is a graph illustrating a relationship between an air volume between blades per each blade of the fan 1 and a position of the blade. On the basis of Fig. 7, a relationship between an air volume between blades per each blade of the fan 1 constituting the sirocco fan 100 and a position of the blade will be explained. In Fig. 7, a ordinate axis represents the air volume (m^3/min) between blades per each blade, and a abscissa axis represents the position of the blade, respectively. Further, in Fig. 7, closed circles denote a relationship between an air volume between blades per each blade and a position of the blade at an operating point (1), open rhombuses denote a relationship between an air volume between blades per each blade and a position of the blade at an operating point (2), and closed triangles denote a relationship between an air volume between blades per each blade and a position of the blade at an operating point (3), respectively.

[0029] Incidentally, in Fig. 7, the air volume between blades per each blade of the fan 1 represented by the ordinate axis is illustrated such that a case of an air flow that is directed from an inner peripheral side of the blade to an outer peripheral side thereof is defined as positive, and a case of the air flow that is directed from the outer peripheral side of the blade to the inner peripheral side thereof is defined as negative. In addition, in Fig. 7, a position of the blade indicated by a abscissa axis is represented by an hour hand of a clock. That is, the position of the blade is expressed by replacing the same with a position of the hour hand of the clock from 0 minutes past 0 o'clock to 0 minutes past 12 o'clock. Furthermore, the operating point (1) through the operating point (3) illustrated in Fig. 7 indicate the same operating points as the operating points (1) through (3) illustrated in Fig. 4.

[0030] As illustrated in Fig. 7, it is found that when a position of the blade is in the vicinity of 30 minutes past 10 o'clock, the more the operating point moves to the open side, the larger the air volume between blades becomes, and the more the operating point moves to the closure side, the smaller the air volume between blades becomes. Moreover, it is found that in an area other than that from 30 minutes past 9 o'clock to 30 minutes past 11 o'clock, a significant difference is not expressed in the air volume between blades. When the air volume between blades is defined as Qi (in a case that the number of the blades is set to be 40, i = 1 through 40), with regard to a noise value SPL and a fan-input value W, below described formulas (formula (1) and formula (2)) are satisfied in principle.

$$\text{Formula (1)} \quad SPL \propto \Sigma 10 \cdot \log_{10} Qi^6$$

$$\text{Formula (2)} \quad W \propto \Sigma Qi^3$$

[0031] Accordingly, the more the distribution of the air volume Qi between blades is uniform, the smaller the noise value SPL and the fan-input value W become. That is, since the distribution of the air volume Qi between blades is uniform in a case of the operating point (1), which is near the surging area, the specific noise Ks becomes minimum, as illustrated in Fig. 4. At this moment, as described above, although the more the operating point is close to the surging area, namely the more the operating point is near $Lo/Ho = f(\xi_0)$, the smaller the specific noise Ks becomes. However, if the operating point exceeds $Lo/Ho = f(\xi_0)$, the operating point becomes to be included in the surging area and the specific noise Ks is deteriorated by contraries. On the other hand, the more the operating point is spaced apart from the surging area to the open side, the more the static pressure fluctuation is increased at the tongue portion (denoted by a reference numeral 2b1 in Fig. 3) of a casing, or in an area where a distance between a bell mouth and a fan is small. As a result, the abnormal sound becomes easy to occur.

[0032] Consequently, while setting $0 < n \leq 1$, and $L_0/H_0 = n \times f(\xi_0)$, in a case of a condition of the small loss coefficient (with a large air volume and a small ventilation resistance), namely within the range of $0.1 \leq \xi_0 \leq 0.4$, when the minimum

n in which the abnormal sound does not occur is obtained, it is found that n = 0.75. Accordingly, in the case of the condition of the small loss coefficient (with a large air volume and a small ventilation resistance), namely within the range of $0.1 \leq \xi_0 \leq 0.4$, if $0.75f(\xi_0) \leq L_0/H_0 \leq f(\xi_0)$, it is found that the air flow having a small specific noise Ks, in which an abnormal sound does not occur, can be formed.

[0033] Although a case of the scroll-casing height H_0 = 246mm is explained in the aforementioned description, a case in which a dimension of the scroll-casing height is generalized will be explained. Here, each of the equations is set as $H = kH_0$, $L = kL_0$, and $D = kD_0$ where k is defined as a constant. When the dimension is varied, below described formulas (Formula (3) and Formula (4)) hold with regard to P and Q by a similarity rule. Here, N is defined as a rotation number.

$$\text{Formula (3):} \quad P = P_0(D/D_0)^2(N/N_0)^2$$

$$\text{Formula (4):} \quad Q = Q_0(D/D_0)^3(N/N_0)$$

[0034] If N/N_0 is eliminated from the formula (3) and the formula (4), and the formulas (3) and (4) are set in order, a formula (5) holds.

$$\text{Formula (5):} \quad P_0/Q_0^2 = P/Q^2(D/D_0)^4$$

if $\xi = P/Q^2$, and $D = kD_0$ are substituted in the formula (5), a formula (6) holds.

$$\text{Formula (6):} \quad \xi_0 = k^4\xi$$

If the formula (6), $H = kH_0$, and $L = kL_0$ are used,
$0.1 \leq \xi_0 \leq 0.4$ can be generalized into $0.1 \leq k^4\xi \leq 0.4$, and
$0.75f(\xi_0) \leq L_0/H_0 \leq f(\xi_0)$ can be generalized into $0.75f(k^4\xi) \leq L/H \leq f(k^4\xi)$.

[0035] That is, in a case that the fan 1 is used for an air-conditioning apparatus in which a heat exchanger is provided on a downstream side of a fan, and in the case of the condition of the small loss coefficient (with a large air volume and a small ventilation resistance), since the noise is small and the velocity distribution in a width direction of the heat exchanger approaches a uniform state by means of lengthening the fan width, the compressor can be operated without unnecessarily increasing a power consumption therefor.

[0036] Next, a case that the sirocco fan 100 is of a one-side suction type will be explained. In this case, it is sufficient to replace the above-described L with L/2, and Q with Q/2, respectively. Further, if $g(\xi) = f\{P/(Q/2)^2\}$, an equation: $g(k^4\xi) = 1.39788(k^4\xi)^2 - {}^2\ 2.1108(k^4\xi) + 1.8$ is satisfied, and an inequality: $1.5g(k^4\xi) \leq L/H \leq 2g(k^4\xi)$ is also satisfied. That is, in the case that the sirocco fan 100 is of the one-side suction type, a fan unit having a small specific noise Ks, in which an abnormal sound does not occur, can be formed by means of satisfying the inequality: $1.5g(k^4\xi) \leq L/H \leq 2g(k^4\xi)$ within the range of $0.1 \leq k^4\xi \leq 0.4$.

[0037] Although a case of a single body of the sirocco fan 100 is explained in the above-described explanation, an operating point in a case in which the sirocco fan 100 is mounted on a fan unit for an air-conditioning apparatus, a dehumidifier, an air cleaner, and so forth, can be similarly determined as well. In such a case, it is sufficient to obtain the rotation number N_1 and the air volume Q_1 of the fan unit, and to obtain the static pressure P_1 using the rotation number N_1 and the air volume Q_1 from the P-Q characteristic of the single body of the sirocco fan 100. Incidentally, in a case that m pieces of the fans are mounted on the fan unit, it is sufficient to obtain the loss coefficient while considering an air volume of one piece of the fan to be Q_1/m, and a static pressure thereof to be P_1.

[0038] As is clear from the above described explanation, in a case that the sirocco fan 100 is a both-side suction type, a stable air flow with small specific noise can be formed by means of satisfying the equation: $0.75f(k^4\xi) \leq L/H \leq f(k^4\xi)$, within the range of $0.1 \leq k^4\xi \leq 0.4$. Further, in the case that the sirocco fan 100 is that of the one-side suction type, a stable air flow with small specific noise can be formed by means of satisfying the equation: $1.5g(k^4\xi) \leq L/H \leq 2g(k^4\xi)$, within the range of $0.1 \leq k^4\xi \leq 0.4$.

[0039] Fig. 8 is a schematic cross-sectional view illustrating a longitudinal cross-sectional construction of the bell mouth 3. Fig. 9 is a perspective view of the sirocco fan 100 illustrating an area α of the bell mouth 3. Fig. 10 is an enlarged

view of a part of the area α illustrating an rms value of a static pressure fluctuation on a wall surface of the part of the area α when a step is not provided. Fig. 11 is the enlarged view of the part of the area α illustrating the rms value of the static pressure fluctuation on the wall surface of the part of the area α when the step is provided. On the basis of Fig. 8 through Fig. 11, an aspect of the bell mouth 3 to be attached to the sirocco fan 100 will be explained while comparing the one in which the bell mouth 3 is attached in such a way that a step is formed on a side surface of the scroll casing 2, and the one in which the bell mouth 3 is attached in such a way that a step is not formed on the side surface of the scroll casing 2.

[0040] The longitudinal cross-sectional construction of the bell mouth 3 illustrated in Fig. 8 will be explained, while end points on a sirocco fan 100 side (end points on a minimum opening portion of the bell mouth 3) are defined as a point A and a point A' (point symmetric to the point A about a center of the bell mouth 3), respectively, end points on the other side (end points on a maximum opening portion of the bell mouth 3) are defined as a point B and a point B' (point symmetric to the point B about a center of the bell mouth 3), an intersecting point of a straight line that is drawn from the point B in a direction of the fan 1 and a side surface of a scroll casing 2 is defined as a point C, an intersecting point of a straight line that is drawn from the point B' in the direction of the fan 1 and the side surface of the scroll casing side 2 is defined as a point C', and an intersecting point of a line segment AA' and an extension line of the rotation axis of the fan 1 is defined as a point O.

[0041] That is, when BC > 0, the bell mouth 3 is attached in such away that a step is formed on the side surface of the scroll casing 2, and when BC = 0, the bell mouth 3 is attached in such a way that a step is not formed on the side surface of the scroll casing 2. Incidentally, the exemplification is made under the condition, in which a length of BC is 5 [mm], and the rms value of the static pressure fluctuation in the area other than the area α is approximately 0[Pa] when BC >0. In Fig. 9 through Fig. 11, the static pressure fluctuation in the one in which the step is formed on the side surface of the scroll casing 2, and the static pressure fluctuation in the one in which the step is not formed on the side surface of the scroll casing 2 are compared with respect to the attaching manners of the bell mouth 3, as illustrated in Fig. 8.

[0042] Hereinbelow, a definitional equation of the rms value of the static pressure fluctuation is shown.

$$\text{Formula (7)} \quad P_s(t) = P_s + P_s' = (t)$$

$$\text{Formula (8)} \quad \text{rms value} = \{(\Sigma P_s'(t)^2/N\}^{0.5}$$

Where, P_s denotes a mean time value, and $P_s'(t)$ denotes a fluctuation value of the static pressure.

The larger the rms value of the static pressure fluctuation on the wall surface is, the larger the noise generated from the wall surface becomes. From Fig. 10 and Fig. 11, it is found that the static pressure fluctuation of the one attached so as to form a step on the side surface of the scroll casing 2 is smaller than static pressure fluctuation of the one attached so as to form no step. Accordingly, it is sure that if the step is formed on the side surface of the scroll casing 2, the generated noise can be reduced.

[0043] Fig. 12 is a longitudinal cross-sectional view illustrating a schematic cross-sectional construction of the sirocco fan 100. Fig. 13 is a see-through perspective view illustrating the sirocco fan 100 in the see-through manner. On the basis of Fig. 12 and Fig. 13, an area in the sirocco fan 100 where the rms value of the static pressure fluctuation is large will be explained. Further, in Fig. 12, a portion that is located closest to an outer peripheral portion of the fan 1 at a curved portion of the scroll casing 2 constituting the sirocco fan 100 extending from the air path 2c to the blowing-outlet 2b is illustrated as a tongue portion 4.

[0044] Fig. 13 illustrates that on an intersection line of a plane surface that passes through the point A, the point O, and the point A' shown in Fig. 8 and the tongue portion 4, a point having the smallest distance from the fan 1 is defined as a point D, a point on the bell mouth 3, which is closest to the point D is defined as a point E, a point that is positioned at an angle of 65 degrees relative to the point E in a counter rotation direction of the fan 1 about the point O as a center is defined as a point F, a point that is positioned at an angle of 40 degrees relative to the point F in a counter rotation direction of the fan 1 about the point O as a center is defined as a point G, a point that is positioned at an angle of 40 degrees relative to the point F in a rotation direction of the fan 1 about the point O as a center is defined as a point H, and a point that is positioned at an angle of 180 degrees relative to the point F in a rotation direction of the fan 1 about the point O as a center is defined as a point 1.

[0045] In a case that the area is thus defined, it is found that the area in the sirocco fan 100 having a large rms value of the static pressure fluctuation is an area of an approximately circular arc HFG connecting the point H, the point F, and the point G. Accordingly, when a length of a line segment BC in the circular arc HFG is defined as X, and a length of the line segment BC in an approximately circular arc HIG (a circular arc connecting the point H, the point I, and the

point G) is defined as Y, if the bell mouth 3 that is configured to satisfy an inequality $X > Y \geq 0$ within a range of $L/H \leq f(k^4\xi)$ or $L/H \leq g(k^4\xi)$ is employed, the rms value of the static pressure fluctuation can be reduced and the noise can also be reduced.

[0046] As illustrated in Fig. 10 and Fig. 11, in a case that the step is not formed on the side surface of the scroll casing 2, the rms value of the static pressure fluctuation in the area of the circular ark HFG is 7Pa at the maximum, however, in a case that the step is formed on the side surface of the scroll casing 2, the rms value of the static pressure fluctuation in the area of the circular arc HFG is 1Pa or less at the maximum. That is, the noise caused by the bell mouth 3 as a sound source is reduced by means of forming the step on the side surface of the scroll casing 2. The reason is considered such that a distance from the fan 1 is enlarged by an amount of the step formed, namely by an amount of the length of the line segment BC, and thereby the static pressure fluctuation that occurs by the rotation of the fan 1 is suppressed.

[0047] Fig. 14 is a graph illustrating a P-Q characteristic of the sirocco fan 100 in a case of passing the operating point B. On the basis of Fig. 14, the P-Q characteristic in a case of passing the operating point B of the sirocco fan 100 in which the step is formed on the side surface of the scroll casing 2, and the P-Q characteristic in a case of passing the operating point B of the sirocco fan 100 in which the step is not formed on the side surface of the scroll casing 2 will be explained. In Fig. 14, closed circles denote a P-Q characteristic of the sirocco fan 100 with no step formed on the side surface of the scroll casing 2, and open circles denote a P-Q characteristic of the sirocco fan 100 with the step formed on the side surface of the scroll casing 2, respectively. Further, in Fig. 14, a ordinate axis indicates static pressure P [Pa], and the abscissa axis indicates an air volume Q[m^3/min].

[0048] As illustrated in Fig. 14, when the surging areas are compared in the sirocco fan 100 with the step formed on the side surface of the scroll casing 2, and the sirocco fan 100 with no step formed on the side surface of the scroll casing 2, it is found that the surging area in the former is on the open side in relation to that in the latter. In a case that the sirocco fan 100 with the step formed on the side surface of the scroll casing 2 is mounted on a fan unit of an air-conditioning apparatus, a dehumidifier, an air cleaner or the like, there is sometimes a case in which the width dimension of the sirocco fan 100 cannot be lengthened due to a dimensional restriction of the fan unit. That is, in a case that the width dimension is short, and the operating point is located on the open side in relation to the surging area where the specific noise becomes minimum, since the surging area can be caused to approach the operating point, it is effective for reducing the noise.

[0049] Fig. 15 is a plan view illustrating a schematic entire construction of a ceiling suspended indoor unit 110 on which the sirocco fan 100 is mounted. Fig. 16 is a cross-sectional view illustrating a longitudinal cross-sectional construction of the ceiling suspended indoor unit 110. On the basis of Fig. 15 and Fig. 16, a static pressure fluctuation of a case that the sirocco fan 100 with the step formed on the side surface of the scroll casing 2 is mounted on the ceiling suspended indoor unit 110 will be explained. Incidentally, in Fig. 15, a case that two sirocco fans 100 are mounted and suction spaces 5 are formed on the respective side surfaces in the width direction is illustrated. In addition, in Fig. 16, an air flow is indicated by arrows.

[0050] In a case that the sirocco fan 100 with the step formed on the side surface of the scroll casing 2 is mounted on the ceiling suspended indoor unit 110, the suction space is reduced due to the formed step by just that much, and this is sometimes a cause of increasing the noise. In accordance with the explanation described above, an area where the rms value of the static pressure fluctuation is large is the circular ark HFG, and an influence of the distance from the fan 1, to the rms value of the static pressure fluctuation is small in other areas. Accordingly, if the sirocco fan 100 with the step formed in the area of the circular arc HFG, is mounted on the ceiling suspended indoor unit 110, the step can be positioned on the downstream side of the suction inlet 2a, and a decrease of the suction space 5 can be reduced.

[0051] Fig. 17 is a table showing a noise value in the ceiling suspended indoor unit 110. On the basis of Fig. 17, a noise value of the noise generated from the ceiling suspended indoor unit 110 on which the sirocco fan 100 with the step formed on the side surface of the scroll casing 2 is mounted, and the noise value of the noise generated from the ceiling suspended indoor unit 110 on which the sirocco fan 100 with no step formed on the side surface of the scroll casing 2 is mounted, will be explained. Incidentally, the step is assumed to be formed in an area of the circular arc HFG. Further, the noise values in a case that the blowing-out air volume is set to be 16m^3/min are respectively shown.

[0052] As shown in Fig. 17, in the case that the blowing-out air volume is set to be 16m^3/min, it is found that the noise value of the sirocco fan with the step formed in the area of the circular arc HFG is 42.4[dB], and the noise value of the sirocco fan with no step formed in the area of the circular arc HFG is 44.0[dB]. Thus, the noise value can be reduced by means of forming the step in the area of the circular ark HFG. As described above, a decrease of the suction space 5 can be suppressed and the noise value can be reduced by means of forming a step in the area of the circular arc HFG.

Second Embodiment

[0053] Fig. 18 is a schematic constructional view illustrating a schematic construction of an air-conditioning apparatus 150 with respect to a second embodiment of the present invention. A construction of the air-conditioning apparatus 150 will be explained on the basis of Fig. 18. This air-conditioning apparatus 150 is the one where the sirocco fan 100 with

respect to the first embodiment is mounted. This sirocco fan 100 is to be used for an indoor unit constituting the air-conditioning apparatus 150 while being mounted in the vicinity of a heat exchanger. Incidentally, in this second embodiment, a different point from the above-described first embodiment will be mainly explained, and the same numerals are attached to the same parts as that in the first embodiment, and the explanation will be omitted.

[0054] This air-conditioning apparatus 150 is constructed while connecting a compressor 151, a condensing heat exchanger 152, a throttling apparatus 153, and the evaporating heat exchanger 154 in series with refrigerant piping. In the above-mentioned construction, the sirocco fan 100 with respect to the first embodiment is provided in the indoor unit where the condensing heat exchanger 152 or the evaporating heat exchanger 154 is installed. That is, the sirocco fan 100 is provided in the vicinity of the condensing heat exchanger 152 or the evaporating heat exchanger 154 that is installed in the indoor unit, and is provided with a function to supply air to the condensing heat exchanger 152 or the evaporating heat exchanger 154.

[0055] The compressor 151 is an apparatus to suck in refrigerant flowing in the refrigerant piping, and to compress the refrigerant so that the refrigerant is brought to a high temperature and high pressure state. The condensing heat exchanger 152 is an apparatus to perform a heat-exchange operation between the air and the refrigerant, and to condense and liquefy the refrigerant. The throttling apparatus 153 is an apparatus to decompress and expand the refrigerant. The evaporating heat exchanger 154 is an apparatus to perform the heat exchange operation between the air and the refrigerant, and to evaporate and gasify the refrigerant. The noise transmitted to a house interior can be reduced by means of mounting the sirocco fan 100 with respect to the first embodiment on the indoor unit provided with the condensing heat exchanger 152 or the evaporating heat exchanger 154, that constitutes the air-conditioning apparatus 150.

[0056] At this moment, an operation of the air-conditioning apparatus 150 will be briefly explained. An arrow illustrated in Fig. 18 indicates a flowing direction of the refrigerant. The refrigerant gas that is compressed and brought to a high temperature and high pressure state by means of the compressor 151 flows into the condensing heat exchanger 152. In the condensing heat exchanger 152, the refrigerant is condensed by being heat-exchanged with the air, and is brought to a liquid refrigerant or a gas-liquid two-phase refrigerant of low temperature and high pressure. The refrigerant that flows out from the condensing heat exchanger 152 is thereafter decompressed by means of the throttling apparatus 153, and flows into the evaporating heat exchanger 154 upon becoming the liquid refrigerant of low temperature and low pressure, or the gas-liquid two-phase refrigerant. In the evaporating heat exchanger 154, the refrigerant is evaporated by being heat-exchanged with the air, is brought to a refrigerant gas of high temperature and low pressure, and is again sucked into the compressor 151. At a time of a heating operation, the condensing heat exchanger 152 is mounted on the indoor unit, and at a time of a cooling operation, the evaporating heat exchanger 154 is mounted on the indoor unit.

[0057] In a case that a loss coefficient is small and a fan width is long, a velocity distribution in a width direction of a heat exchanger approaches a uniform state, and thereby a heat-transmitting area of the heat exchanger can be effectively used, compared with a case that the fan width is short and the velocity distribution is not uniform. Therefore, a temperature difference between air and a refrigerant, which is necessary to obtain a predetermined air-conditioning capability, becomes small, a compressor input becomes small, and a low noise is realized. Further, in a case that the loss coefficient is small, even when the fan diameter is not enlarged, the noise can be reduced by lengthening the fan width. Furthermore, in an air-conditioning apparatus provided with a plurality of fans having a short fan width, a noise value of the air-conditioning apparatus at a predetermined operating point can be reduced and a velocity distribution of the heat exchanger in a width direction can be caused to approach a uniform state, by means of replacing the fan with a fan having a long fan width, even when the number of the fans is decreased.

Claims

1. Method of designing a sirocco fan (100) including a scroll casing (2) including a suction inlet (2a) for sucking in air, a blowing-outlet (2b) for blowing out the air, and an air path (2c) from the suction inlet (2a) to the blowing-outlet (2b); a fan (1) housed in the scroll casing, for sucking in the air from the suction inlet (2a) and blowing out the air from the blowing-outlet (2b) by means of rotation-driving; and a bell mouth (3) attached to the suction inlet (2a) of the scroll casing (2), in which the suction inlet (2a) is formed on an extension line of a rotation axis of the fan (1) and on both side surfaces of the scroll casing (2),
characterized in that
the method comprises:

a step of satisfying an equation: $f(k^4\xi) = 0.34947(k^4\xi)^2 - 1.0554(k^4\xi) + 1.8$, and an inequality: $0.75f(k^4\xi) \leq L/H \leq f(k^4\xi)$ within a range of $0.1 \leq k^4\xi \leq 0.4$,

when a ventilation resistance in the air path (2c) is defined as P[Pa], an amount of air sucked in from the suction inlet (2a) is defined as Q[m^3/min], a width in a direction of a rotation axis of the fan is defined as L[mm], k is defined

as a constant, a height of the scroll casing is defined as H = 246k[mm], and P/Q^2 is defined as a loss coefficient ξ $[Pa/(m^3/min)^2]$.

2. The method of designing the sirocco fan (100) according to Claim 1, further comprising a step of satisfying the following inequality: $X > Y \geq 0$ within a range of $L/H \leq f(k^4\xi)$ when a curved portion extending from the air path (2c) to the blowing-outlet (2b) of the scroll casing (2) that is closest to the outer peripheral portion of the fan (1) serves as a tongue portion (2b1, 4) and when in a longitudinal cross-section of the bell mouth (3), an end point at a minimum opening portion of the bell mouth (3) is defined as a point A, a point that is symmetric to the point A about a center of the bell mouth (3) is defined as a point A', an end point at a maximum opening portion of the bell mouth (3) is defined as a point B, a point that is symmetric to the point B about the center of the bell mouth (3) is defined as B', an intersecting point of a straight line that is drawn from the point B in a direction toward the fan (1) and a side surface of the scroll casing (2) is defined as a point C, an intersecting point of a straight line that is drawn from the point B' in the direction toward the fan (1) and the side surface of the scroll casing (2) is defined as a point C', an intersecting point of a line segment AA' and the extension line of the rotation axis of the fan (1) is defined as a point O, a point on an intersecting line of a plane surface that passes through the point A, the point O, and the point A', and the tongue portion (2b1, 4), having the smallest distance from the fan (1) is defined as a point D, a point on the bell mouth (3), which is closest to the point D is defined as a point E, a point that is positioned at an angle of 65 degrees relative to the point E in a counter rotation direction of the fan (1) about the point O as a center is defined as a point F, a point that is positioned at an angle of 40 degrees relative to the point F in the counter rotation direction of the fan (1) about the point O as a center is defined as a point G, a point that is positioned at an angle of 40 degrees relative to the point F in a rotation direction of the fan (1) about the point O as a center is defined as a point H, a point that is positioned at an angle of 180 degrees relative to the point F in the rotation direction of the fan (1) about the point O as a center is defined as a point I, a length of a line segment BC in an approximately circular arc HFG connecting the point H, the point F, and the point G is defined as X, and a length of a line segment BC in an approximately circular arc HIG connecting the point H, the point I, and the point G is defined as Y.

3. A method of designing a sirocco fan inclucing a scroll casing (2) including a suction inlet (2a) for sucking in air, a blowing-outlet (2b) for blowing out the air, and an air path (2c) from the suction inlet (2a) to the blowing-outlet (2b); a fan (1) housed in the scroll casing (2), for sucking in the air from the suction inlet (2a) and blowing out the air from the blowing-outlet (2c) by means of rotation-driving; and a bell mouth (3) attached to the suction inlet (2a) of the scroll casing (2), wherein the suction inlet (2a) is formed on an extension line of a rotation axis of the fan (1) and on one side surface of the scroll casing (2),
characterized in that
the method comprises:

a step of satisfying an equation: $g(k^4\xi) = 1.39788(k^4\xi)^2 - 2.1108(k^4\xi) + 1.8$, and an inequality: $1.5g(k^4\xi) \leq L/H \leq 2g(k^4\xi)$ within a range of $0.1 \leq k^4\xi \leq 0.4$,

when a ventilation resistance in the air path (2c) is defined as P[Pa], an amount of air sucked in from the suction inlet (2a) is defined as $Q[m^3/min]$, a width in a direction of a rotation axis of the fan (1) is defined as L[mm], k is defined as a constant, a height of the scroll casing (2) is defined as H = 246k[mm], and P/Q^2 is defined as a loss coefficient $\xi[Pa/(m^3/min)^2]$.

4. The method of designing the sirocco fan (100) according to Claim 3, further comprising a step of satisfying the following inequality: $X > Y \geq 0$ within a range of $L/H \leq g(k^4\xi)$, when a curved portion extending from the air path (2c) to the blowing-outlet (2b) of the scroll casing (2) that is closest to the outer peripheral portion of the fan (1) serves as a tongue portion, and when in a longitudinal cross-section of the bell mouth (3), an end point at a minimum opening portion of the bell mouth (3) is defined as a point A, a point that is symmetric to the point A about a center of the bell mouth (3) is defined as a point A', an end point at a maximum opening portion of the bell mouth (3) is defined as a point B, a point that is symmetric to the point B about the center of the bell mouth (3) is defined as B', an intersecting point of a straight line that is drawn from the point B in a direction toward the fan (1) and a side surface of the scroll casing (2) is defined as a point C, an intersecting point of a straight line that is drawn from the point B' in the direction toward the fan (1) and the side surface of the scroll casing (2) is defined as a point C', an intersecting point of a line segment AA' and the extension line of the rotation axis of the fan (1) is defined as a point 0, a point on an intersecting line of a plane surface that passes through the point A, the point O, and the point A', and the tongue portion (2b1, 4), having the smallest distance from the fan (1) is defined as a point D, a point on the bell mouth (3), which is closest to the point D is defined as a point E, a point that is positioned at an angle of 65 degrees relative to the point E in a counter rotation direction of the fan (1) about the point O as a center is defined

as a point F, a point that is positioned at an angle of 40 degrees relative to the point F in the counter rotation direction of the fan (1) about the point O as a center is defined as a point G, a point that is positioned at an angle of 40 degrees relative to the point F in a rotation direction of the fan (1) about the point O as a center is defined as a point H, a point that is positioned at an angle of 180 degrees relative to the point F in the rotation direction of the fan (1) about the point O as a center is defined as a point I, a length of a line segment BC in an approximately circular arc HFG connecting the point H, the point F, and the point G is defined as X, and a length of a line segment BC in an approximately circular arc HIG connecting the point H, the point I, and the point G is defined as Y.

Patentansprüche

1. Verfahren zum Gestalten eines Sirocco-Lüfters (100) enthaltend ein Spiralgehäuse (2) mit einem Saugeinlass (2a) zum Einsaugen von Luft, einem Blasauslass (2b) zum Ausblasen der Luft und einem Luftpfad (2c) von dem Saugeinlass (2a) zu dem Blasauslass (2b); einen Lüfter (1), der in dem Spiralgehäuse aufgenommen ist, zum Einsaugen der Luft von dem Saugeinlass (2a) und Ausblasen der Luft von dem Blasauslass (2b) mittels eines Drehantriebs; und eine Glockenöffnung (3), die an dem Saugeinlass (2a) des Spiralgehäuses (2) angebracht ist, in welchem der Saugeinlass (2a) auf einer Verlängerungslinie einer Drehachse des Lüfters (1) und in beiden Seitenflächen des Spiralgehäuses (2) ausgebildet ist,
dadurch gekennzeichnet, dass
das Verfahren aufweist:

einen Schritt des Genügens einer Gleichung:

$$f(k^4\xi) = 0{,}64947(k^4\xi)^2 - 1{,}0554(k^4\xi) + 1{,}8\,,$$

und einer Ungleichung:

$$0{,}75\,f(k^4\xi) \le L/H \le f(k^4\xi)$$

innerhalb eines Bereichs von

$$0{,}1 \le k^4\xi \le 0{,}4\,,$$

wenn ein Lüftungswiderstand in dem Luftpfad (2c) definiert ist als P[Pa], eine von dem Saugeinlass (2a) eingesaugte Luftmenge definiert ist als Q[m^3/min], eine Breite in einer Richtung einer Drehachse des Lüfters definiert ist als L [mm], k definiert ist als eine Konstante, eine Höhe des Spiralgehäuses definiert ist als H=246k[mm], und P/Q^2 definiert ist als ein Verlustkoeffizient ξ [Pa/(m^3/min)^2.

2. Verfahren zum Gestalten des Sirocco-Lüfters (100) nach Anspruch 1, weiterhin aufweisend einen Schritt des Genügens der folgenden Ungleichung: $X>Y\geq 0$ innerhalb eines Bereichs von $L/H\leq f(k^4\xi)$, wenn ein gekrümmter Bereich, der sich von dem Luftpfad (2c) zu dem Blasauslass (2b) des Spiralgehäuses (2), der dem äußeren Umfangsbereich des Lüfters (1) am nächsten ist, erstreckt, als ein Zungenbereich (2b1, 4) dient, und wenn in einem Längsquerschnitt der Glockenöffnung (3) ein Endpunkt in einem minimalen Öffnungsbereich der Glockenöffnung (3) als ein Punkt A definiert ist, ein Punkt, der in Bezug auf eine Mitte der Glockenöffnung (3) symmetrisch zu dem Punkt A ist, als ein Punkt A' definiert ist, ein Endpunkt in einem maximalen Öffnungsbereich der Glockenöffnung (3) als ein Punkt B definiert ist, ein Punkt, der in Bezug auf die Mitte der Glockenöffnung (3) symmetrisch zu dem Punkt B ist, als B' definiert ist, ein Schnittpunkt einer geraden Linie, die von dem Punkt B in einer Richtung zu dem Lüfter (1) hin gezogen ist, und einer Seitenfläche des Spiralgehäuses (2) als ein Punkt C definiert ist, ein Schnittpunkt einer geraden Linie, die von dem Punkt B' in der Richtung zu dem Lüfter (1) hin gezogen ist, und der Seitenfläche des Spiralgehäuses (2) als ein Punkt C' definiert ist, ein Schnittpunkt eines Liniensegments AA' und der Verlängerungslinie der Drehachse des Lüfters (1) als ein Punkt O definiert ist, ein Punkt auf einer Schnittlinie einer ebenen Oberfläche, die durch den Punkt A, den Punkt O und den Punkt A' hindurchgeht, und des Zungenbereichs (2b1, 4), der den kleinsten Abstand von dem Lüfter (1) hat, definiert ist als ein Punkt D, ein Punkt in der Glockenöffnung (3), der dem Punkt D am nächsten ist, definiert ist als ein Punkt E, ein Punkt, der unter einem Winkel von 65 Grad relativ

zu dem Punkt E in einer Gegendrehrichtung des Lüfters (1) um den Punkt O als eine Mitte positioniert ist, definiert ist als ein Punkt F, ein Punkt, der unter einem Winkel von 40 Grad relativ zu dem Punkt F in der Gegendrehrichtung des Lüfters (1) um den Punkt O als eine Mitte positioniert ist, definiert ist als ein Punkt G, ein Punkt, der unter einem Winkel von 40 Grad relativ zu dem Punkt F in einer Drehrichtung des Lüfters (1) um den Punkt O als eine Mitte positioniert ist, definiert ist als ein Punkt H, ein Punkt, der unter einem Winkel von 180 Grad relativ zu dem Punkt F in der Drehrichtung des Lüfters (1) um den Punkt O als eine Mitte positioniert ist, definiert ist als ein Punkt I, eine Länge eines Liniensegments BC in einem angenähert kreisförmigen Bogen HFG, der den Punkt H, den Punkt F und den Punkt G verbindet, definiert ist als X, und eine Länge eines Liniensegments BC in einem angenähert kreisförmigen Bogen HIG, der den Punkt H, den Punkt I und den Punkt G verbindet, definiert ist als Y.

3. Verfahren zum Gestalten eines Sirocco-Lüfters enthaltend ein Spiralgehäuse (2) mit einem Saugeinlass (2a) zum Einsaugen von Luft, einem Blasauslass (2b) zum Ausblasen der Luft und einem Luftpfad (2c) von dem Saugeinlass (2a) zu dem Blasauslass (2b); einen Lüfter (1), der in dem Spiralgehäuse (2) aufgenommen ist, zum Einsaugen der Luft von dem Saugeinlass (2a) und Ausblasen der Luft von dem Blasauslass (2c) mittels eines Drehantriebs; und eine Glockenöffnung (3), die an dem Saugeinlass (2a) des Spiralgehäuses (2) angebracht ist, wobei der Saugeinlass (2a) auf einer Verlängerungslinie einer Drehachse des Lüfters (1) und in einer Seitenfläche des Spiralgehäuses (2) ausgebildet ist, **dadurch gekennzeichnet, dass**
das Verfahren aufweist:

einen Schritt des Genügens einer Gleichung:

$$g(k^4\xi)=1{,}39788(k^4\xi)^2-2{,}1108(k^4\xi)+1{,}8,$$

und einer Ungleichung:

$$1{,}5g(k^4\xi)\leq L/H\leq 2g(k^4\xi)$$

innerhalb eines Bereichs von

$$0{,}1\leq k^4\xi\leq 0{,}4,$$

wenn ein Lüftungswiderstand in dem Luftpfad (2c) definiert ist als P[Pa], eine von dem Saugeinlass (2a) eingesaugte Luftmenge definiert ist als Q[m^3/min], eine Breite in einer Richtung einer Drehachse des Lüfters (1) definiert ist als L[mm], k definiert ist als eine Konstante, eine Höhe des Spiralgehäuses (2) definiert ist als H=246k[mm], und P/Q^2 definiert ist als ein Verlustkoeffizient ξ[Pa/(m^3/min)^2].

4. Verfahren zum Gestalten des Sirocco-Lüfters (100) nach Anspruch 3, weiterhin aufweisend einen Schritt des Genügens der folgenden Ungleichung: $X>Y\geq 0$ innerhalb eines Bereichs von $L/H\leq g(k^4\xi)$, wenn ein gekrümmter Bereich, der sich von dem Luftpfad (2c) zu dem Blasauslass (2b) des Spiralgehäuses (2), der dem äußeren Umfangsbereich des Lüfters (1) am nächsten ist, erstreckt, als ein Zugenbereich dient, und wenn in einem Längsquerschnitt der Glockenöffnung (3) ein Endpunkt an einem minimalen Öffnungsbereich der Glockenöffnung (3) definiert ist als ein Punkt A, ein Punkt, der in Bezug auf eine Mitte der Glockenöffnung (3) symmetrisch zu dem Punkt A ist, definiert als ein Punkt A', und ein Endpunkt an einem maximalen Öffnungsbereich der Glockenöffnung (3) definiert ist als ein Punkt B, ein Punkt, der in Bezug auf die Mitte der Glockenöffnung (3) symmetrisch zu dem Punkt B ist, definiert ist als B', ein Schnittpunkt einer geraden Linie, die von dem Punkt B in einer Richtung zu dem Lüfter (1) hin gezogen ist, und einer Seitenfläche des Spiralgehäuses (2) definiert ist als ein Punkt C, ein Schnittpunkt einer geraden Linie, die von dem Punkt B' in der Richtung zu dem Lüfter (1) hin gezogen ist, und der Seitenfläche des Spiralgehäuses (2) als ein Punkt C' definiert ist, ein Schnittpunkt eines Liniensegmentsw AA' und der Verlängerungslinie der Drehachse des Lüfters (1) definiert ist als ein Punkt O, ein Punkt auf einer Schnittlinie einer ebenen Fläche, die durch den Punkt A, den Punkt O und den Punkt A' hindurchgeht, und des Zungenbereichs (2b1, 4), der den kleinsten Abstand von dem Lüfter(1) hat, definiert ist als ein Punkt D, ein Punkt in der Glockenöffnung (3), der dem Punkt D am nächsten ist, definiert ist als ein Punkt E, ein Punkt, der unter einem Winkel von 65 Grad relativ zu dem Punkt E in einer Gegendrehrichtung des Lüfters (1) um den Punkt O als eine Mitte positioniert ist, definiert ist als ein Punkt F, ein Punkt, der unter einem Winkel von 40 Grad relativ zu dem Punkt F in der Gegendrehrichtung des Lüfters (1)

um den Punkt O als eine Mitte positioniert ist, definiert ist als ein Punkt G, ein Punkt, der unter einem Winkel von 40 Grad relativ zu dem Punkt F in einer Drehrichtung des Lüfters (1) um den Punkt O als eine Mitte positioniert ist, definiert ist als ein Punkt H, ein Punkt, der unter einem Winkel von 180 Grad relativ zu dem Punkt F in der Drehrichtung des Lüfters (1) um den Punkt O als eine Mitte positioniert ist, definiert ist als ein Punkt I, eine Länge eines Liniensegments BC in einem angenähert kreisförmigen Bogen HFG, der den Punkt H, den Punkt F und den Punkt G verbindet, definiert ist als X, und eine Länge eines Liniensegments BC in einem angenähert kreisförmigen Bogen HIG, der den Punkt H, den Punkt I und den Punkt G verbindet, definiert ist als Y.

Revendications

1. Procédé de conception d'un ventilateur sirocco (100) comprenant un carter spiralé (2) comprenant une entrée d'aspiration (2a) pour aspirer l'air, une sortie de soufflage (2b) pour souffler l'air vers l'extérieur, et un chemin d'air (2c) qui va de l'entrée d'aspiration (2a) jusqu'à la sortie de soufflage (2b) ; un ventilateur (1) logé dans le carter spiralé, destiné à aspirer l'air à partir de l'entrée d'aspiration (2a) et à souffler l'air hors de la sortie de soufflage (2b) au moyen d'un entraînement en rotation ; et une tulipe d'aspiration (3) fixée à l'entrée d'aspiration (2a) du carter spiralé (2), dans lequel l'entrée d'aspiration (2a) est formée sur une ligne d'extension d'un axe de rotation du ventilateur (1) et sur les deux surfaces latérales du carter spiralé (2) ;
caractérisé en ce que :

   le procédé comprend :

   une étape consistant à satisfaire une équation : $f(k^4\xi) = 0{,}34947(k^4\xi)^2 - 1{,}0554(k^4\xi) + 1{,}8$; et une inégalité : $0{,}75f(k^4\xi) \leq L/H \leq f(k^4\xi)$ sur l'intervalle $0{,}1 \leq k^4\xi \leq 0{,}4$;
   lorsque la résistance de ventilation dans le chemin d'air (2c) est définie par P[Pa], la quantité d'air aspirée à partir de l'entrée d'aspiration (2a) est définie par Q[m^3/mn], la largeur dans la direction de l'axe de rotation du ventilateur est définie par L[mm], k est définie comme étant une constante, la hauteur du carter spiralé est définie par H = 246 k[mm], et P/Q^2 est défini comme étant un coefficient de perte ξ[Pa/(m^3/mn)^2].

2. Procédé de conception du ventilateur sirocco (100) selon la revendication 1, comprenant en outre une étape consistant à satisfaire l'inégalité suivante : $X > Y \geq 0$ sur une plage $L/H \leq f(k^4\xi)$ lorsqu'une partie incurvée s'étendant à partir du chemin d'air (2c) jusqu'à la sortie de soufflage (2b) du carter spiralé (2) qui est la plus proche de la partie périphérique extérieure du ventilateur (1) sert de partie de langue (2b1, 4) et lorsque dans une section transversale longitudinale de la tulipe d'aspiration (3), un point d'extrémité au niveau d'une partie d'ouverture minimum de la tulipe d'aspiration (3) est défini par le point A, un point qui est symétrique du point A autour du centre de la tulipe d'aspiration (3) est défini par le point A', un point d'extrémité au niveau d'une partie d'ouverture maximum de la tulipe d'aspiration (3) est défini par le point B, un point qui est symétrique du point B autour du centre de la tulipe d'aspiration (3) est défini par le point B', un point d'intersection d'une ligne droite qui est tracée à partir du point B dans une direction vers le ventilateur (1) et d'une surface latérale du carter spiralé (2) est défini par le point C, un point d'intersection d'une ligne droite qui est tracée à partir du point B' dans la direction vers le ventilateur (1) et de la surface latérale du carter spiralé (2) est défini par le point C', un point d'intersection d'un segment de ligne AA' et de la ligne d'extension de l'axe de rotation du ventilateur (1) est défini par le point O, un point sur une ligne d'intersection d'une surface plane qui passe par le point A, le point O et le point A', et la partie de langue (2b1, 4), présentant la plus petite distance à partir du ventilateur (1) est défini par le point D, un point sur la tulipe d'aspiration (3) qui est le plus proche du point D est défini par le point E, un point qui est positionné sous un angle de 65 degrés par rapport au point E dans le sens de rotation inverse du ventilateur (1) autour du point O en tant que centre est défini par le point F, un point qui est positionné sous un angle de 40 degrés par rapport au point F dans le sens de rotation inverse du ventilateur (1) autour du point O en tant que centre est défini par le point G, un point qui est positionné sous un angle de 40 degrés par rapport au point F dans le sens de rotation du ventilateur (1) autour du point O en tant que centre est défini par le point H, un point qui est positionné sous un angle de 180 degrés par rapport au point F dans le sens de rotation du ventilateur (1) autour du point O en tant que centre est défini par le point I, une longueur d'un segment de ligne BC dans un arc approximativement circulaire HFG reliant le point H, le point F et le point G est définie par X, et une longueur d'un segment de ligne BC dans un arc approximativement circulaire HIG reliant le point H, le point I et le point G est définie par Y.

3. Procédé de conception d'un ventilateur sirocco (100) comprenant un carter spiralé (2) comprenant une entrée d'aspiration (2a) pour aspirer l'air, une sortie de soufflage (2b) pour souffler l'air vers l'extérieur, et un chemin d'air (2c) qui va de l'entrée d'aspiration (2a) jusqu'à la sortie de soufflage (2b) ; un ventilateur (1) logé dans le carter

spiralé, destiné à aspirer l'air à partir de l'entrée d'aspiration (2a) et à souffler l'air hors de la sortie de soufflage (2b) au moyen d'un entraînement en rotation ; et une tulipe d'aspiration (3) fixée à l'entrée d'aspiration (2a) du carter spiralé (2), dans lequel l'entrée d'aspiration (2a) est formée sur une ligne d'extension d'un axe de rotation du ventilateur (1) et sur les deux surfaces latérales du carter spiralé (2) ;
caractérisé en ce que :

le procédé comprend :

une étape consistant à satisfaire une équation : $g(k^4\xi) = 1{,}39788(k^4\xi)^2 - 2{,}1108(k^4\xi) + 1{,}8$; et une inégalité : $1{,}5g(k^4\xi) \leq L/H \leq 2g(k^4\xi)$ sur l'intervalle $0{,}1 \leq k^4\xi \leq 0{,}4$;
lorsque la résistance de ventilation dans le chemin d'air (2c) est définie par P[Pa], la quantité d'air aspirée à partir de l'entrée d'aspiration (2a) est définie par Q[m^3/mn], la largeur dans la direction de l'axe de rotation du ventilateur (1) est définie par L[mm], k est définie comme étant une constante, la hauteur du carter spiralé (2) est définie par H = 246 k[mm], et P/Q^2 est défini comme étant un coefficient de perte ξ[Pa/(m^3/mn)^2].

4. Procédé de conception du ventilateur sirocco (100) selon la revendication 3, comprenant en outre une étape consistant à satisfaire l'inégalité suivante : $X > Y \geq 0$ sur une plage $L/H \leq g(k^4\xi)$ lorsqu'une partie incurvée s'étendant à partir du chemin d'air (2c) jusqu'à la sortie de soufflage (2b) du carter spiralé (2) qui est la plus proche de la partie périphérique extérieure du ventilateur (1) sert de partie de langue, et lorsque dans une section transversale longitudinale de la tulipe d'aspiration (3), un point d'extrémité au niveau d'une partie d'ouverture minimum de la tulipe d'aspiration (3) est défini par le point A, un point qui est symétrique du point A autour du centre de la tulipe d'aspiration (3) est défini par le point A', un point d'extrémité au niveau d'une partie d'ouverture maximum de la tulipe d'aspiration (3) est défini par le point B, un point qui est symétrique du point B autour du centre de la tulipe d'aspiration (3) est défini par le point B', un point d'intersection d'une ligne droite qui est tracée à partir du point B dans une direction vers le ventilateur (1) et d'une surface latérale du carter spiralé (2) est défini par le point C, un point d'intersection d'une ligne droite qui est tracée à partir du point B' dans la direction vers le ventilateur (1) et de la surface latérale du carter spiralé (2) est défini par le point C', un point d'intersection d'un segment de ligne AA' et de la ligne d'extension de l'axe de rotation du ventilateur (1) est défini par le point O, un point sur une ligne d'intersection d'une surface plane qui passe par le point A, le point O et le point A', et la partie de langue (2b1, 4), présentant la plus petite distance à partir du ventilateur (1) est défini par le point D, un point sur la tulipe d'aspiration (3) qui est le plus proche du point D est défini par le point E, un point qui est positionné sous un angle de 65 degrés par rapport au point E dans le sens de rotation inverse du ventilateur (1) autour du point O en tant que centre est défini par le point F, un point qui est positionné sous un angle de 40 degrés par rapport au point F dans le sens de rotation inverse du ventilateur (1) autour du point O en tant que centre est défini par le point G, un point qui est positionné sous un angle de 40 degrés par rapport au point F dans le sens de rotation du ventilateur (1) autour du point O en tant que centre est défini par le point H, un point qui est positionné sous un angle de 180 degrés par rapport au point F dans le sens de rotation du ventilateur (1) autour du point O en tant que centre est défini par le point I, une longueur d'un segment de ligne BC dans un arc approximativement circulaire HFG reliant le point H, le point F et le point G est définie par X, et une longueur d'un segment de ligne BC dans un arc approximativement circulaire HIG reliant le point H, le point I et le point G est définie par Y.

FIG. 1

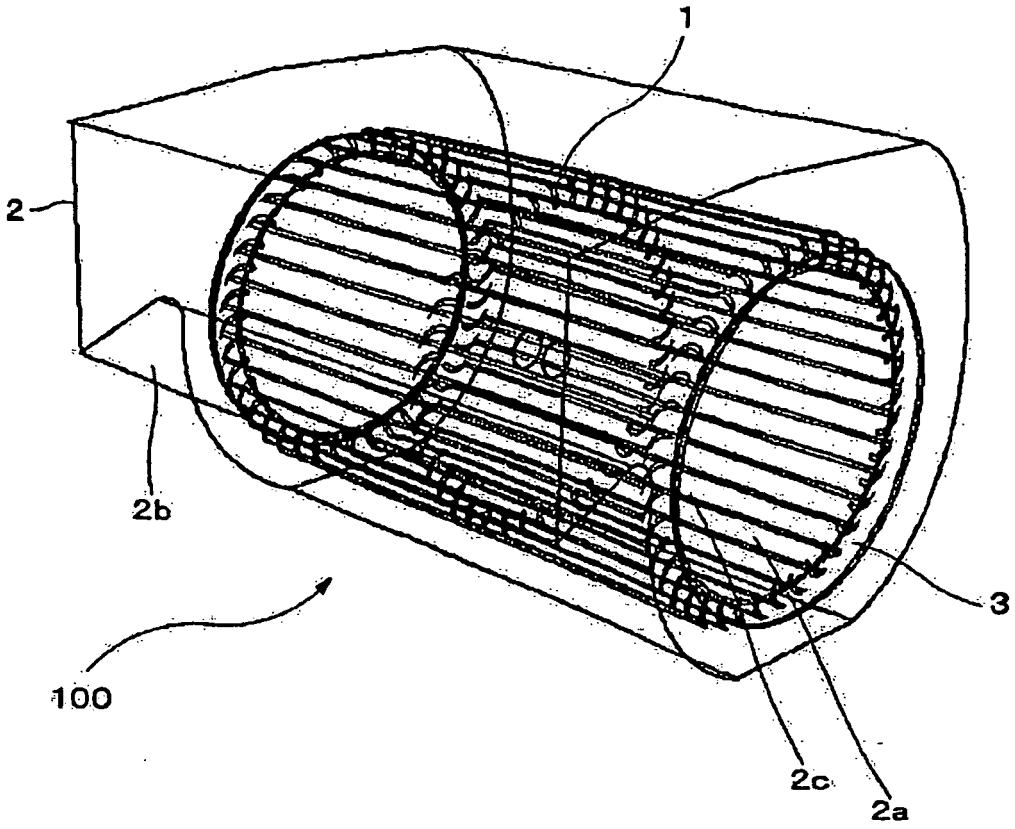


FIG. 2

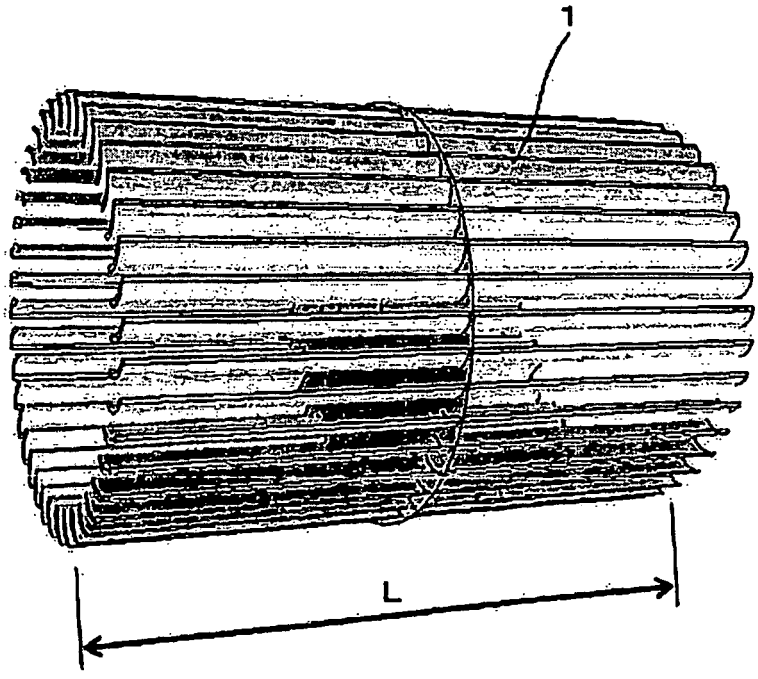


FIG. 3

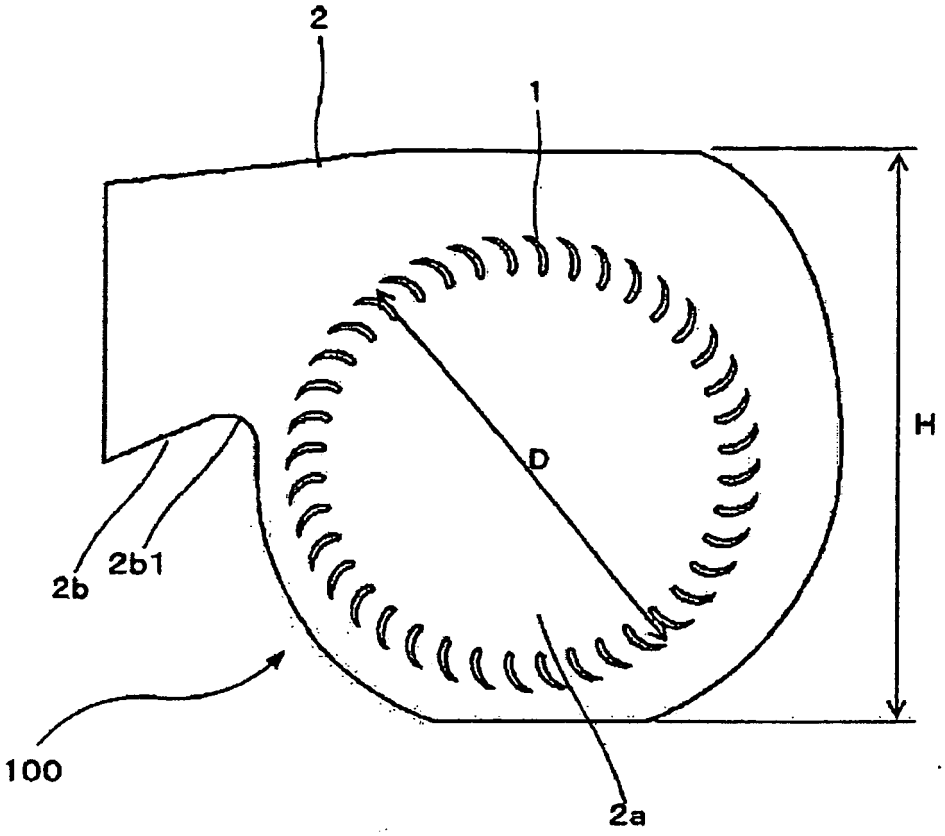


FIG. 4

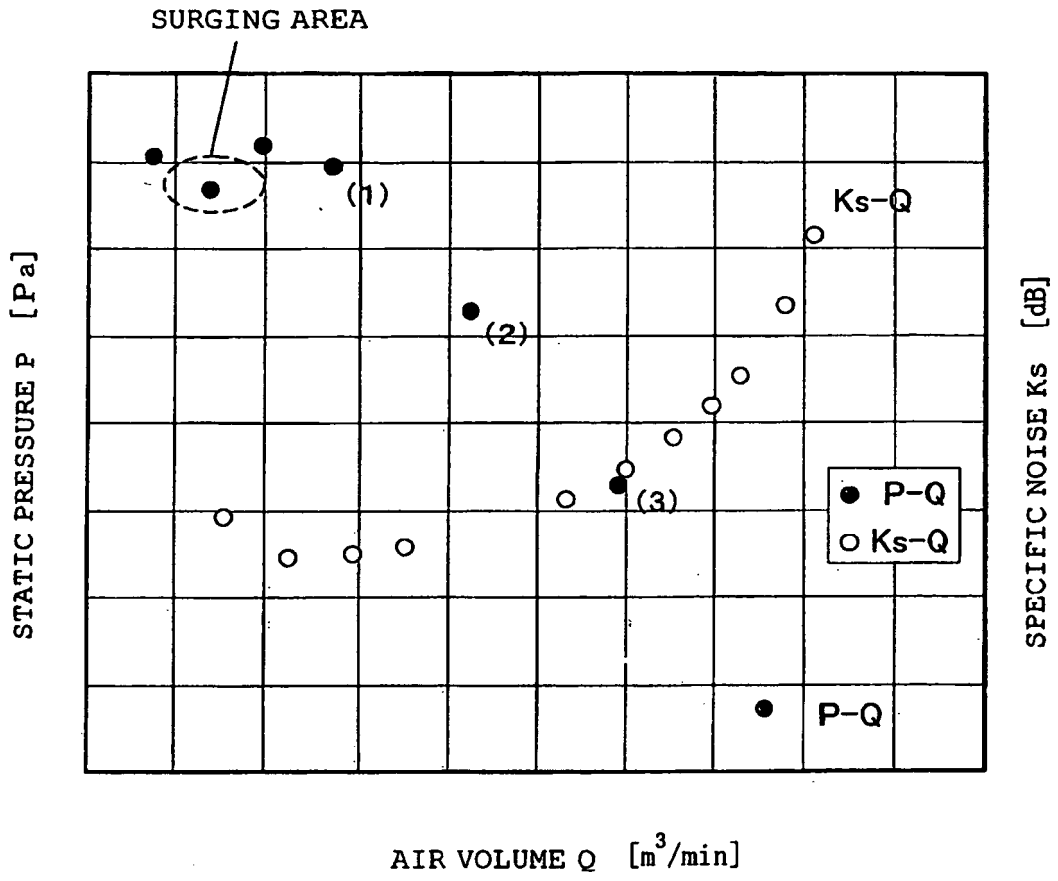

SURGING AREA
(1)
(2)
(3)
Ks-Q
P-Q
Ks-Q
P-Q
STATIC PRESSURE P [Pa]
SPECIFIC NOISE Ks [dB]
AIR VOLUME Q [m3/min]

FIG. 5

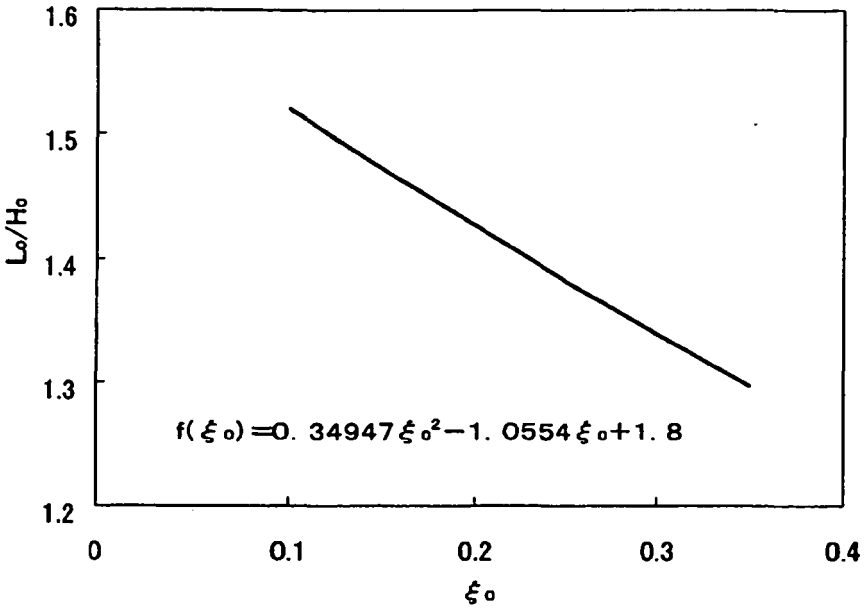


FIG. 6

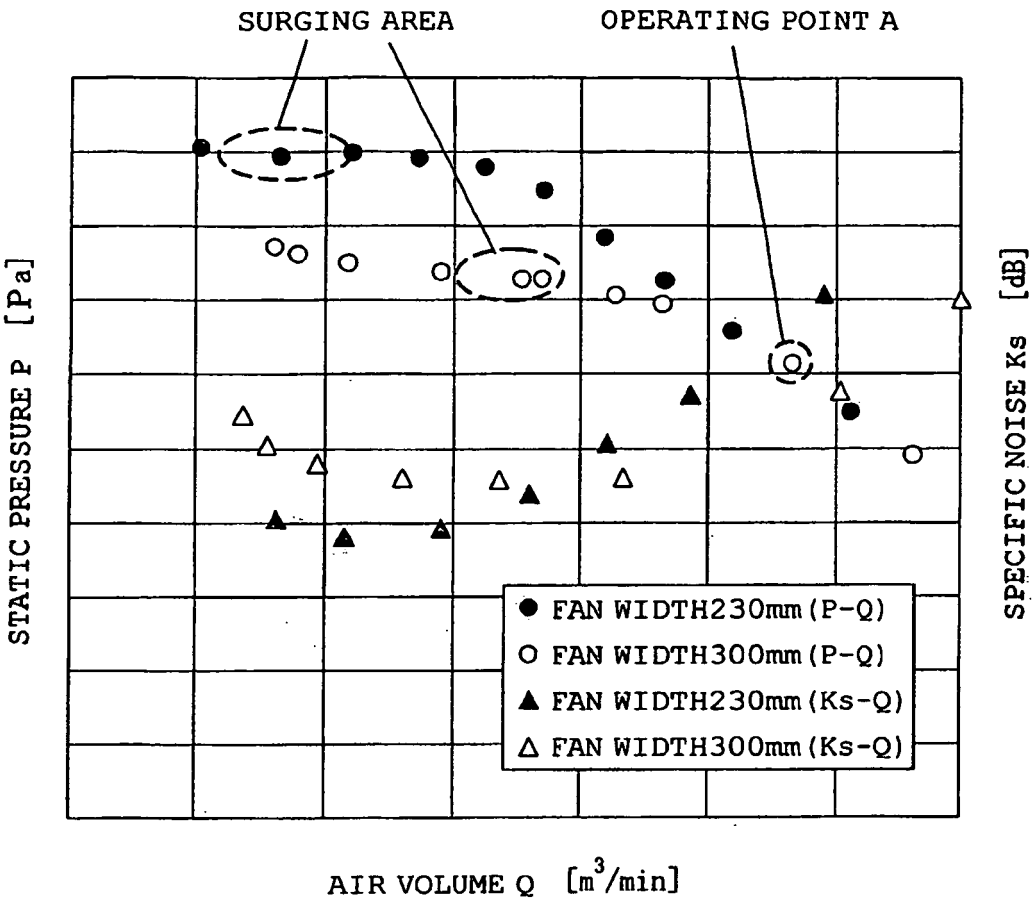

SURGING AREA
OPERATING POINT A
STATIC PRESSURE P [Pa]
SPECIFIC NOISE Ks [dB]
FAN WIDTH230mm (P-Q)
FAN WIDTH300mm (P-Q)
FAN WIDTH230mm (Ks-Q)
FAN WIDTH300mm (Ks-Q)
AIR VOLUME Q [m3/min]

FIG. 7

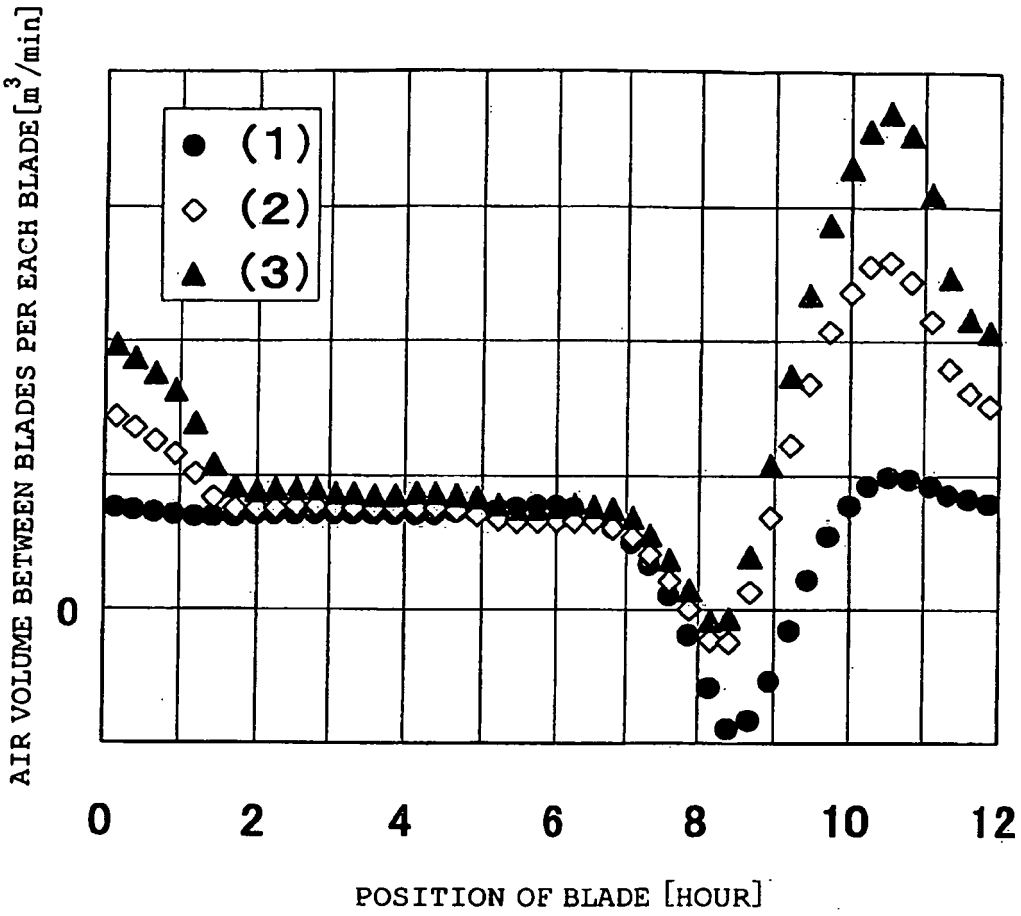

AIR VOLUME BETWEEN BLADES PER EACH BLADE [m3/min]
(1)
(2)
(3)
0
0
2
4
6
8
10
12
POSITION OF BLADE [HOUR]

FIG. 8

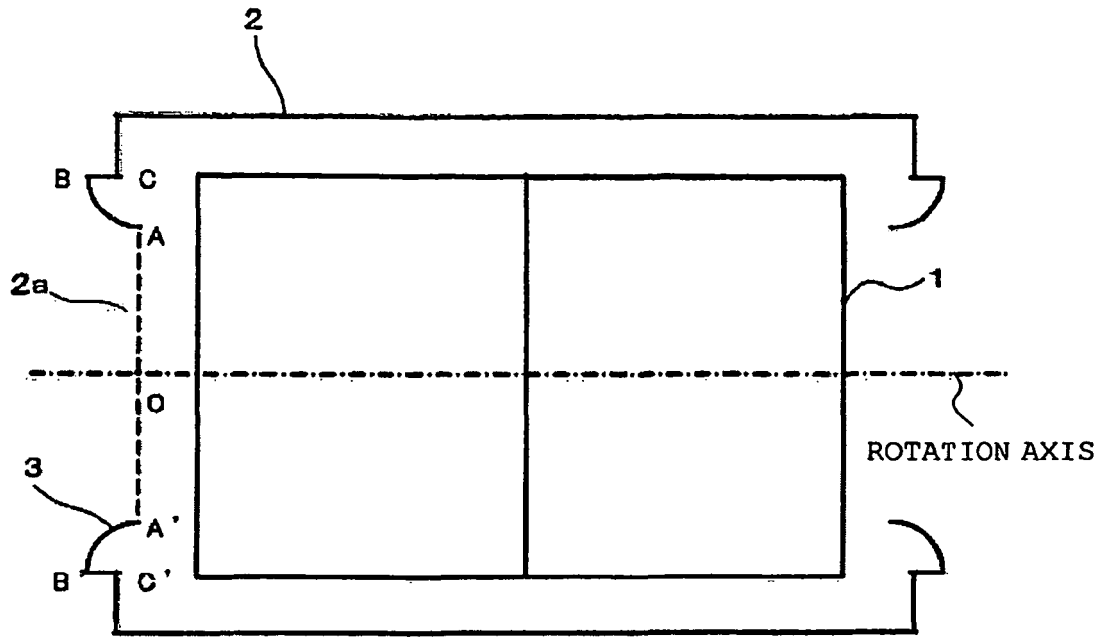


FIG. 9

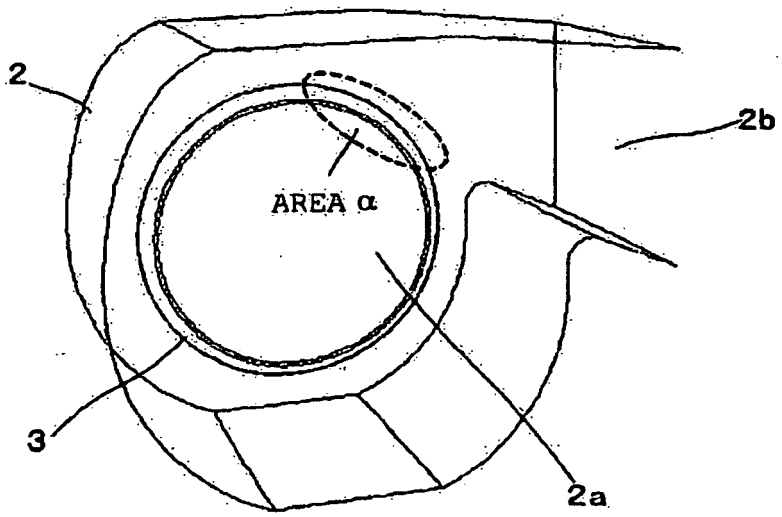


FIG. 10

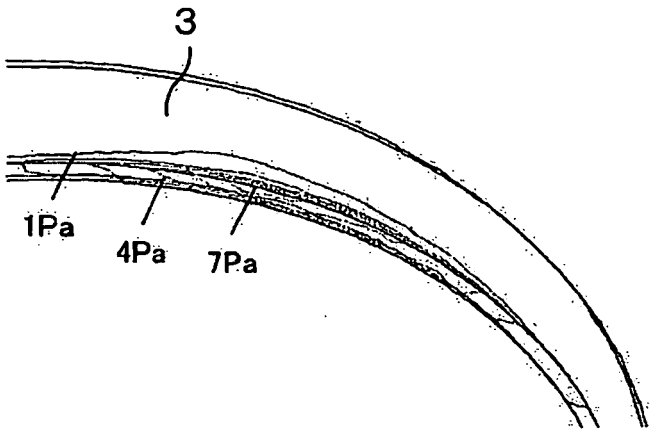


FIG. 11

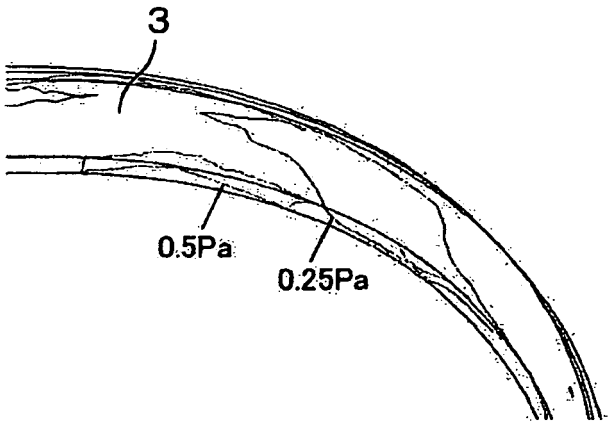


FIG. 12

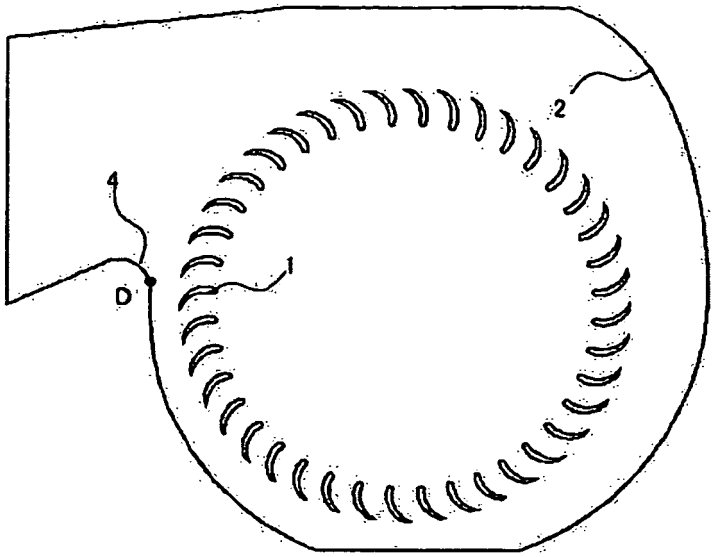


FIG. 13

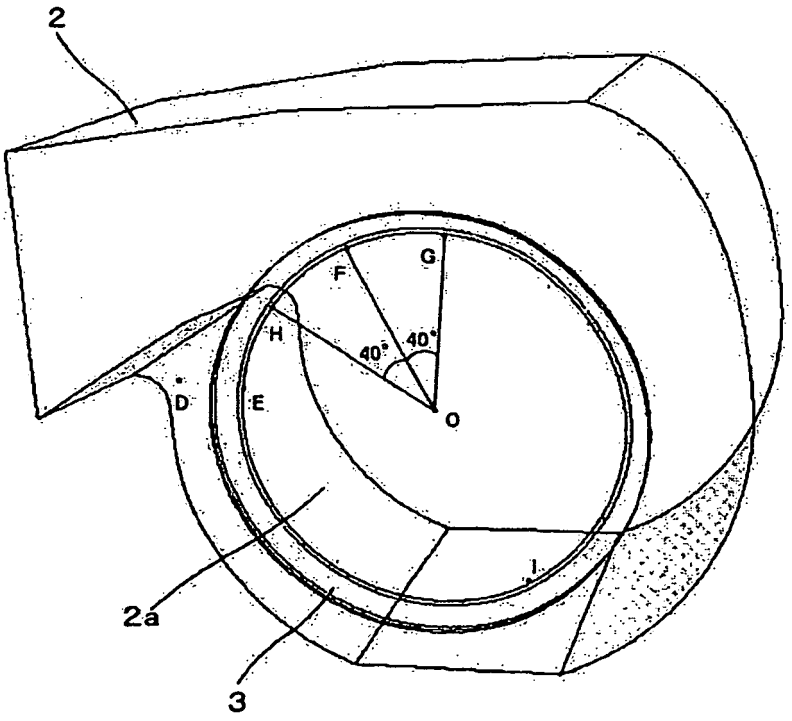


FIG. 14

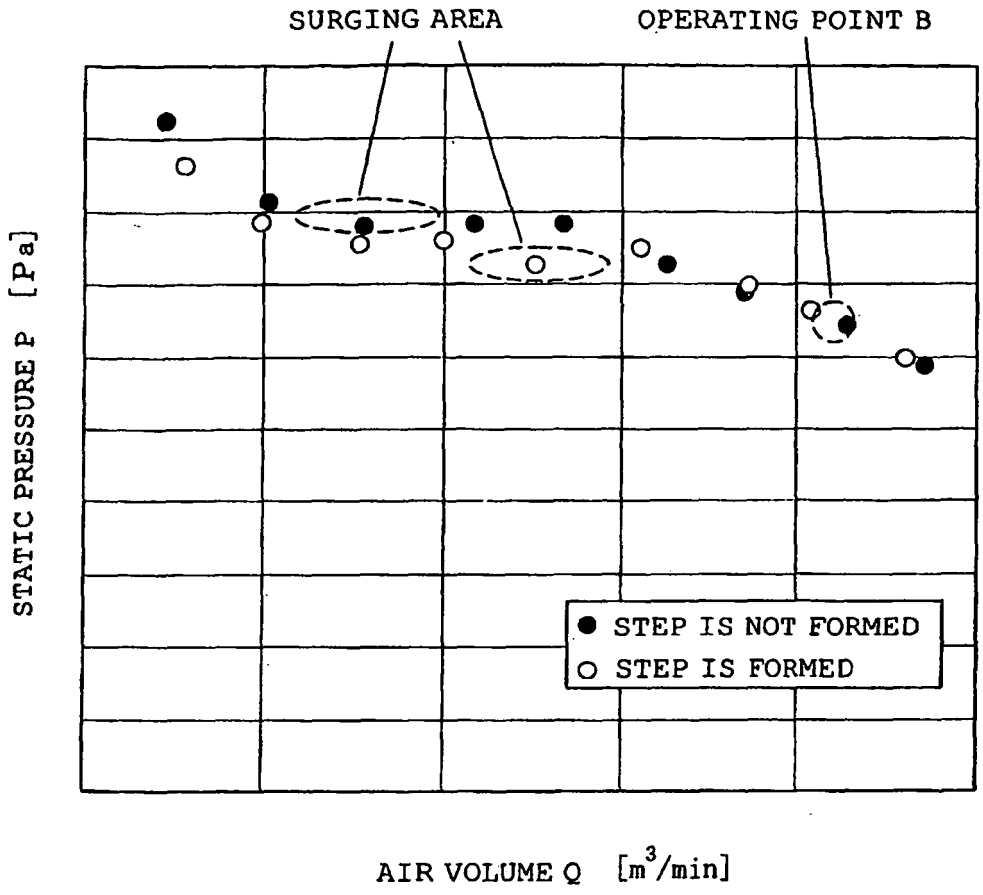

SURGING AREA
OPERATING POINT B
STATIC PRESSURE P [Pa]
STEP IS NOT FORMED
STEP IS FORMED
AIR VOLUME Q [m3/min]

FIG. 15

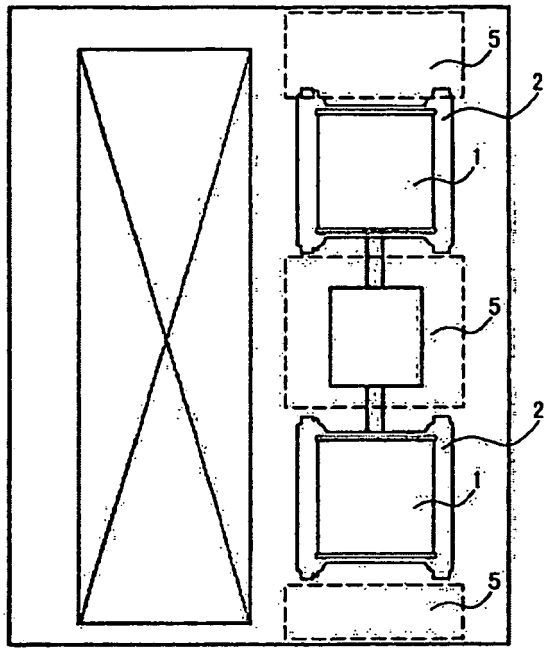


FIG. 16

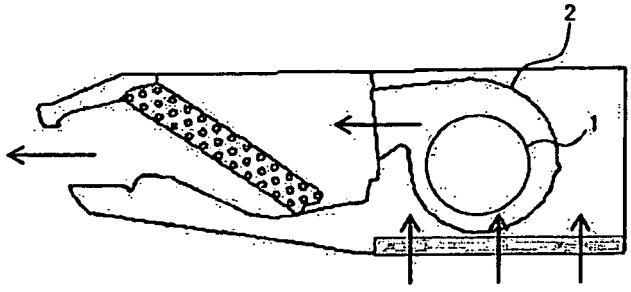
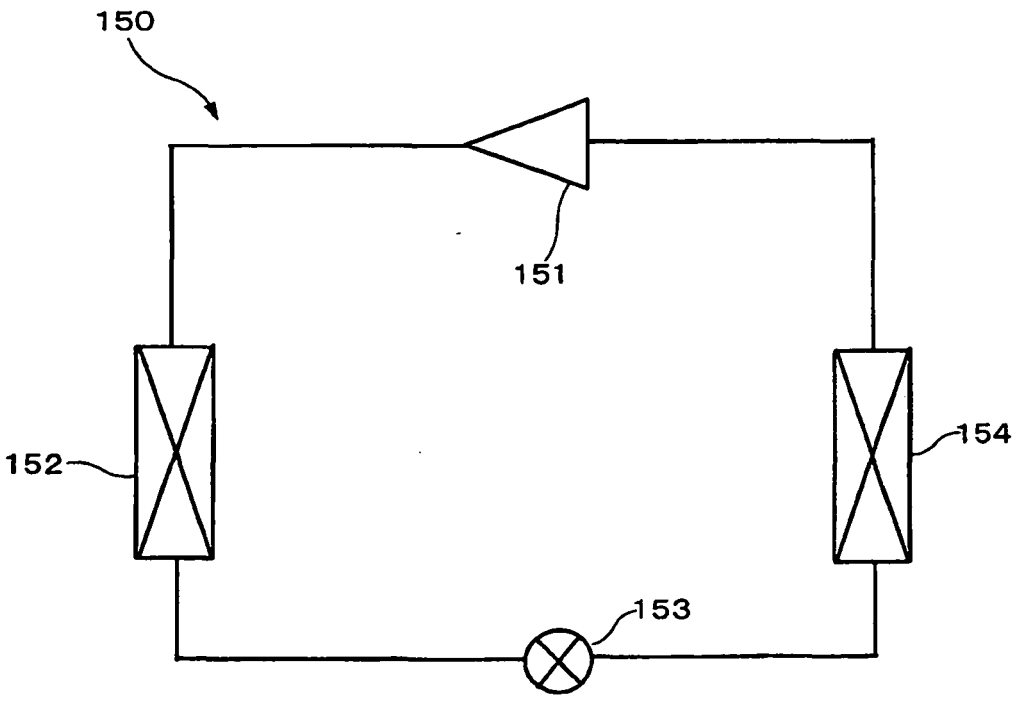


FIG. 17

AREA OF CIRCULAR ARC HFG	NOISE VALUE [dB]
STEP IS NOT FORMED	44.0
STEP IS FORMED	42.4

FIG. 18



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- EP 1703138 A2 **[0002]**
- JP 9126193 B **[0003]**
- JP 11324984 A **[0006]**