United States Patent [19]

Masai et al.

[11] **3,899,266**

[45] **Aug. 12, 1975**

[54] **VORTEX BLOWER**

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[73] Assignee: **Hitachi, Ltd.,** Japan

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[21] Appl. No.: **422,697**

[30] **Foreign Application Priority Data**

Dec. 18, 1972 Japan 47-126106
Feb. 12, 1973 Japan 48-16596

[52] **U.S. Cl.** ..... **415/213 T;** 415/53 T
[51] **Int. Cl.** **F04d 7/00**
[58] **Field of Search** ..... 415/53 T, 213 T

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Primary Examiner—C. J. Husar
Attorney, Agent, or Firm—Craig & Antonelli

[57] **ABSTRACT**

A vortex blower having rotor blades whose edges are contoured to accommodate air flow within the vortex blower, whereby the development of wake caused by the edges of rotor blades in the rear thereof is minimized.

1 Claim, 21 Drawing Figures

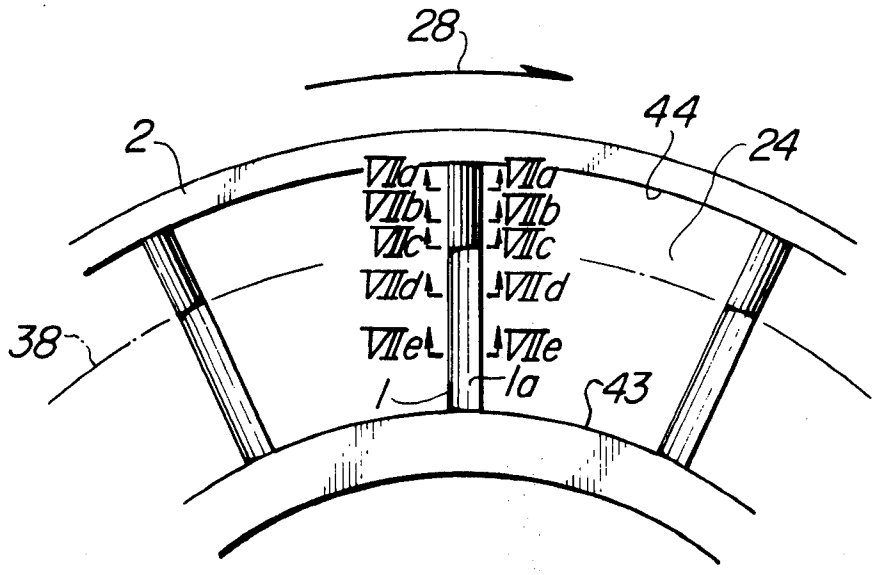


FIG. 1
PRIOR ART

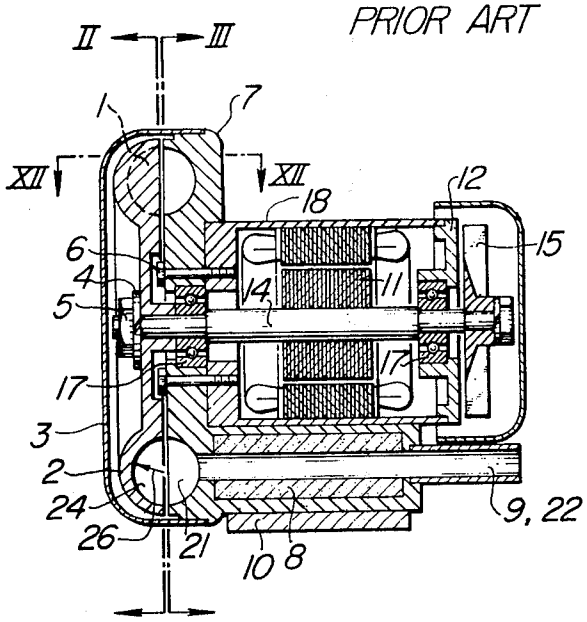


FIG. 2
PRIOR ART

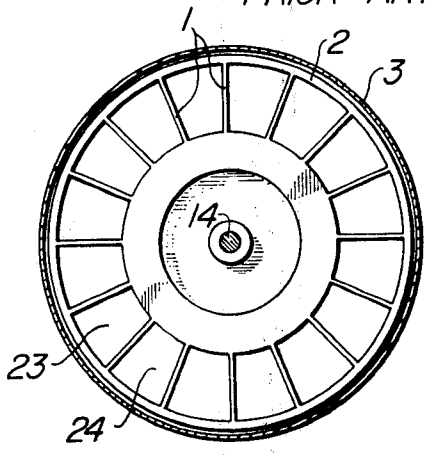


FIG. 3
PRIOR ART

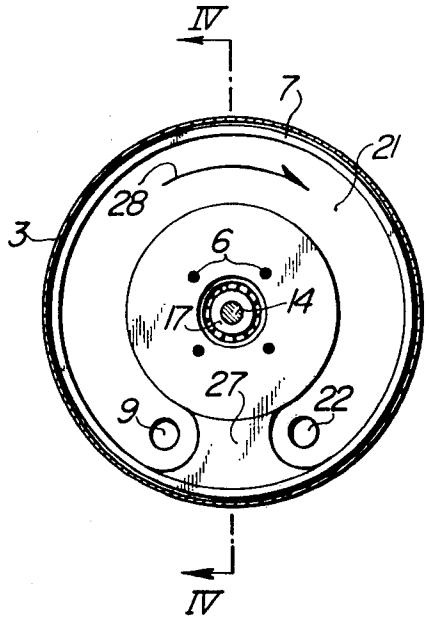


FIG. 4
PRIOR ART

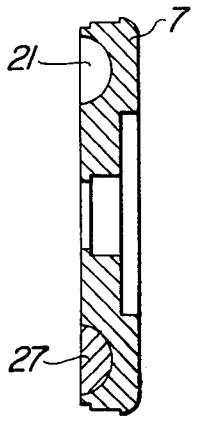


FIG. 5
PRIOR ART

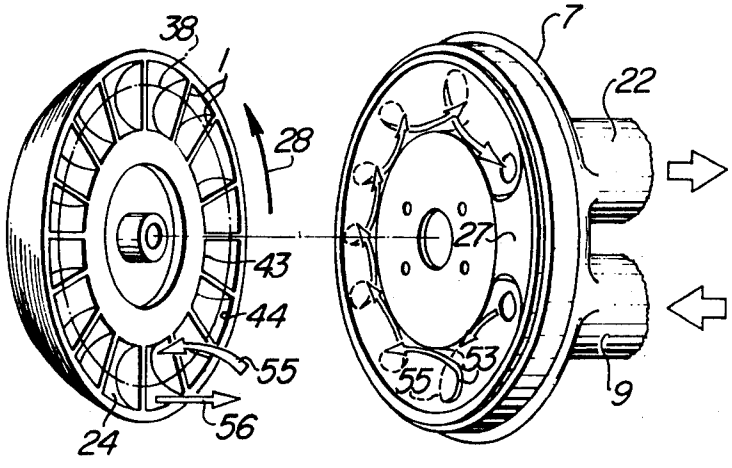


FIG. 6

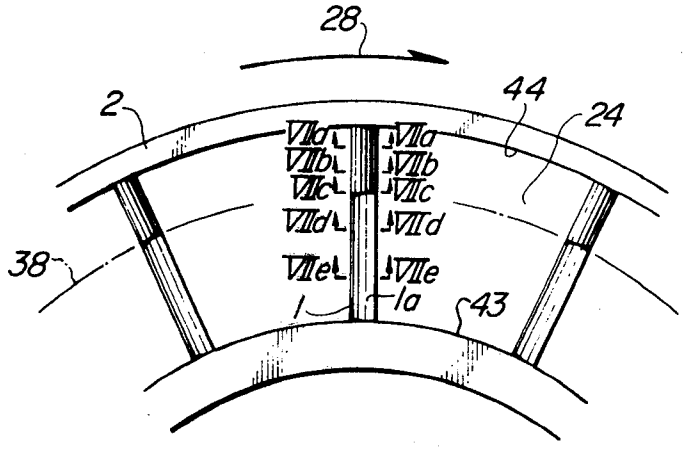


FIG. 7a FIG. 7b FIG. 7c FIG. 7d FIG. 7e

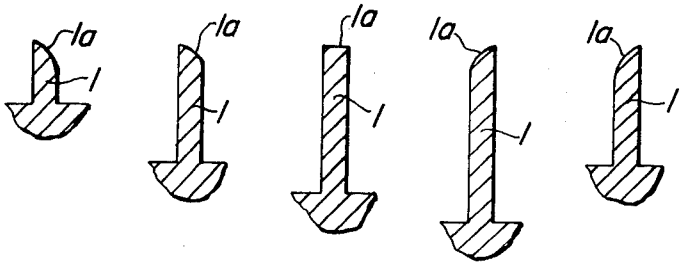


FIG. 8

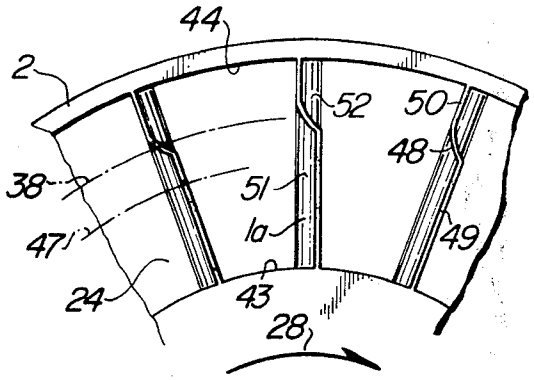


FIG. 9

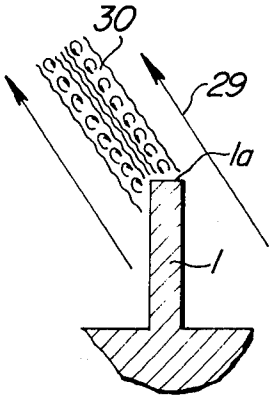


FIG. 10

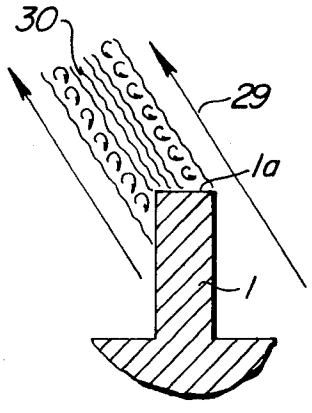


FIG. 11

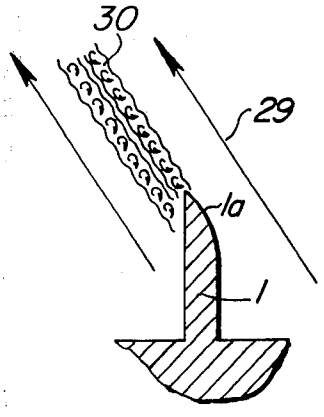


FIG. 12

PRIOR ART

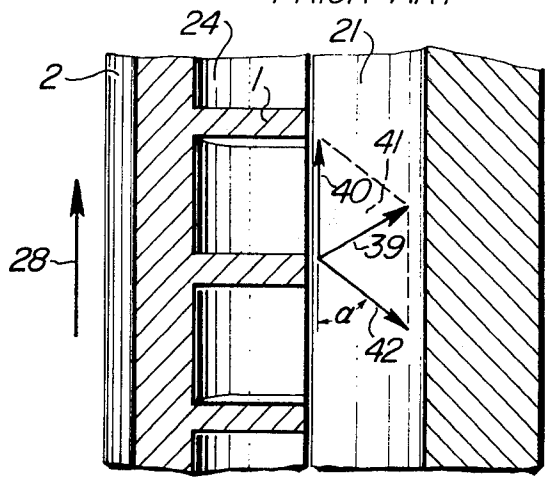


FIG. 13

PRIOR ART

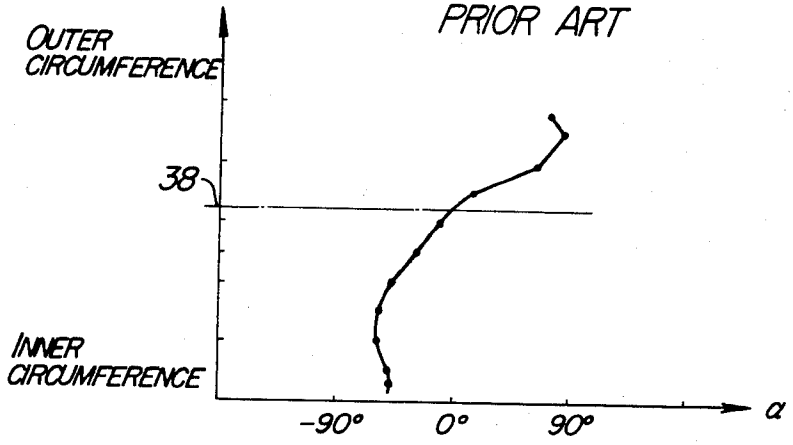


FIG. 14

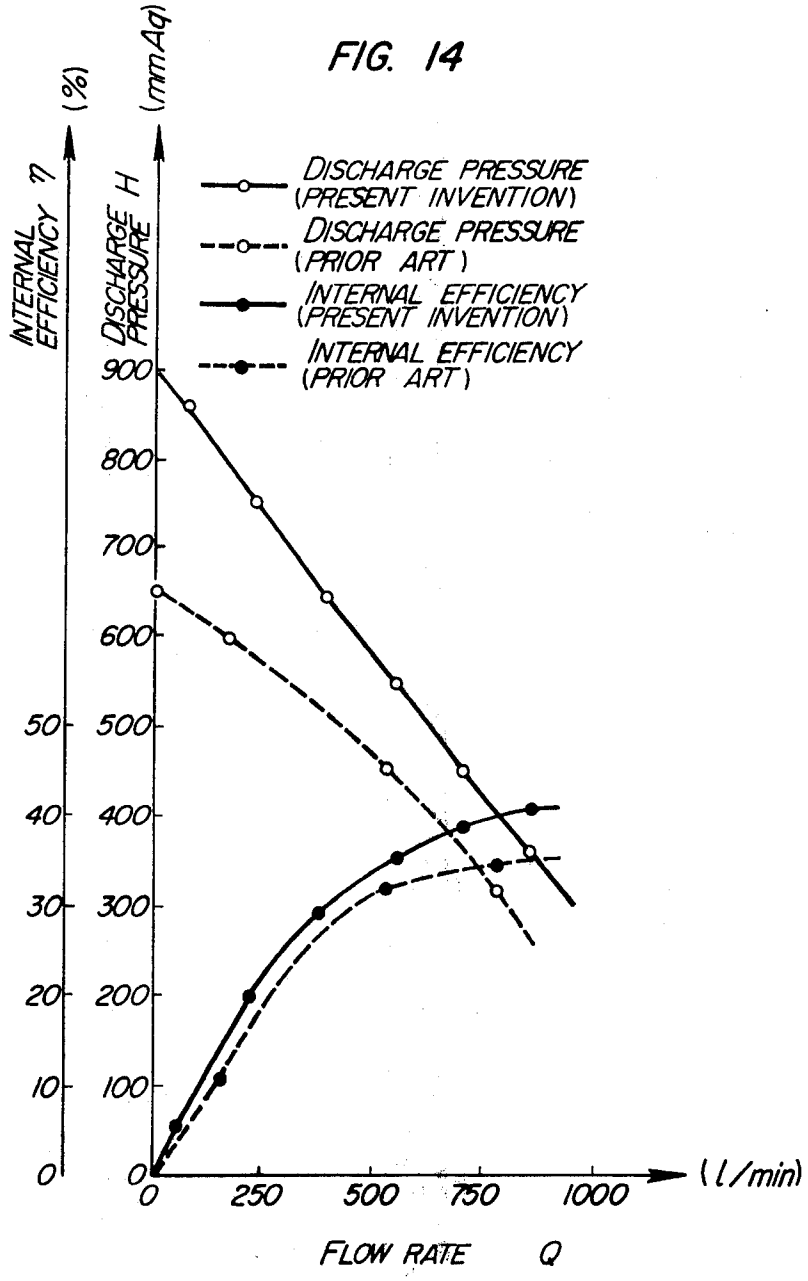

INTERNAL EFFICIENCY η
(%)
DISCHARGE PRESSURE H
(mmAq)
DISCHARGE PRESSURE (PRESENT INVENTION)
DISCHARGE PRESSURE (PRIOR ART)
INTERNAL EFFICIENCY (PRESENT INVENTION)
INTERNAL EFFICIENCY (PRIOR ART)
900
800
700
600
500
400
300
200
100
0
50
40
30
20
10
0
0
250
500
750
1000
(l/min)
FLOW RATE Q

FIG. 15

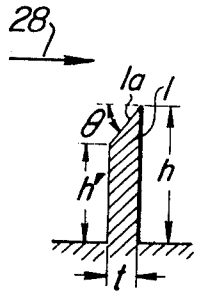


FIG. 16

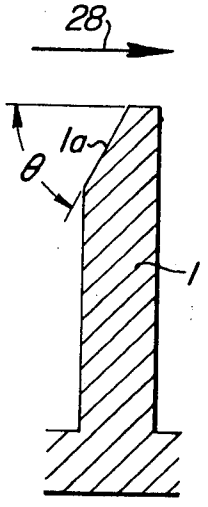
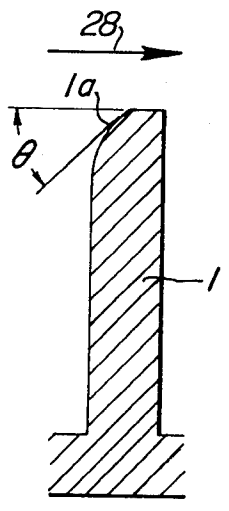


FIG. 17



VORTEX BLOWER

FIELD OF THE INVENTION

This invention relates to a vortex blower and more particularly to the configurations of rotor blades thereof.

BACKGROUND OF THE INVENTION

In general, a vortex blower consists of a stator body having an annular air passage, to which are open a suction port and a discharge port provided in the vicinity of the opposite ends of said passage, a rotor body whose air chamber is divided into compartments by a plurality of rotor blades, and means for driving the rotor. The advantage of the vortex blower is that it provides a discharge pressure three or four times as great as those of other type of blowers and can be manufactured at a lower cost. However, the vortex blower has suferred from disadvantage in that the efficiency is so low that the internal efficiency thereof is 30 to 40 percent at the most and as low as 15 to 20 percent in the operational range thereof. The flowing condition of air within the vortex blower during the rotation of the rotor is such that the air is introduced through the suction port toward the discharge port, while creating spiral flows therein in a manner that the air flow outward of the hydrodynamically neutral line of the air flow created between the air chamber and the air passage is directed from air chamber into air passage, and that the air flow inward of the hydrodynamical neutral line is directed from air passage into air chamber. In this respect, it is observed that there is created wake in the strip stream or in the rear of rotor blades. The increase in the vortex loss due to the wake is considered as one of the causes for the lowered efficiency of the vortex blower, particularly the lowered discharge pressure. Since the wake is created in the vicinity of the edge faces of the rotor blades rotating through the air, the greater the thickness of the rotor blade, the larger will be the wake. Since the thickness of the rotor blade affects the blower efficiency to a considerable degree, the thickness of the blades should preferably be minimized. However, this may be confronted by another limitation arising from the strength requirement as well as ease in machining of a blade. Meanwhile, it may be considered that, from the viewpoint of minimizing the wake or turbulent flow of air due to rotor blades, the contours of rotor blades are steamlined or cut in a manner to accommodate the air flow. However, such has not been proposed for the rotor blades of the conventional vortex blower.

SUMMARY OF THE INVENTION

It is accordingly the principal object of the invention to provide a vortex blower which can minimize the wake loss due to the rotor blades but present improved discharge pressure and internal efficiency.

According to the present invention, there is provided rotor blades whose contours well accommodate the air flow within the blower, thereby minimizing the development of the wake.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 is a cross-sectional view of a conventional type vortex blower;

FIG. 2 is a cross-sectional view of a rotor body alone, taken along the line II — II of FIG. 1;

FIG. 3 is a cross-sectional view of a stator body alone, taken along the line III — III of FIG. 1;

FIG. 4 is a cross-sectional view of the stator body of FIG. 3, taken along the line IV — IV thereof;

FIG. 5 shows condition of air flow within the vortex blower;

FIG. 6 is an enlarged view of part of one embodiment of the invention corresponding to the rotor body of FIG. 2;

FIGS. 7*a* through 7*e* are cross-sectional views of a rotor blade respectively taken along the line VII*a*, VII*b*, VII*c*, BII*d* and VII*e* of FIG. 6;

FIG. 8 is a front view of one example of a rotor blades according to the present invention;

FIGS. 9, 10 and 11 are views illustrating the relationship of the contour of a rotor blade to the wake being created thereby;

FIG. 12 is a cross-sectional view of the blower, taken along the line XII — XII of FIG. 1;

FIG. 13 is a plot showing the variation in an angle α of a rotor blade on the inner and outer circumferences of a rotor;

FIG. 14 is a plot comparing the characteristics of the conventional type vortex blower with those of a blower of the invention;

FIGS. 15 to 17 show the configuration of a rotor blade according to another embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

These and other features and objects of the invention will now be described with reference to the accompanying drawings, and the description will first be given to the construction of the vortex blower of the prior art by referring to FIGS. 1 to 4 and then followed by the embodiments of the invention. FIG. 1 shows the longitudinal cross sectional view of an electric-motor-direct-coupled type vortex blower given in its entirety, in which a rotor blade is shown at 1, a rotor body at 2, a blower convering at 3, a washer at 4, a nut at 5, an attaching bolt for fastening a motor casing 18 to a stator body 7 at 6, and at 8 is a sound shielding material for absorbing the sound from the suction port 9 and discharge port 22. Shown at 10 is a support for rigidly fixing the blower assembly, at 11 a motor rotor, at 12 an end bracket for a motor, at 14 a shaft, at 15 a cooling fan and at 17 a bearing. Designated at 21 is an air passage having a cross section of a semicircle and provided in the stator body 7, at 24 an air chamber divided by a plurality of rotor blades into grooves 23 or compartments having cross sections of a semicircle. FIG. 2 is a plane view of the rotor body 2, showing the cross sectional view of the blower shown in FIG. 1, said plane view being taken along the line II — II of FIG. 1.

FIG. 3 is a cross sectional view of the blower of FIG. 1, taken along the line III — III thereof. The suction port 9 and discharge port 22 are provided so as to be open to the air passage at positions close to the opposite ends of the air passage, while the suction port 9 and discharge port 2 are separated by the partition wall portion 27. As shown in FIG. 3, the rotational direction of the rotor is shown by an arrow 28, while in the case of the reversed direction of rotation of the rotor, the functions of the suction port and discharge port will be reversed. FIG. 4 shows a cross sectional view taken along the line IV — IV of FIG. 3, in which there are shown

cross sections of the semicircular air passage **21** and partition wall portion **27** included in the stator body **7.**

The partition wall portion **27** may be made according to die casting process so as to given an integral construction with the stator body **7.**

Those described are the outline of the vortex blower of the prior art.

The behavior of the air flow within the vortex blower of this sort is as shown in FIG. **5,** and the rotor is provided with a plurality of rotor blades **1** radially extending from the center thereof. The suction air flow **55** introduced through rotor blades runs on the side of the rotational center, i.e., inwardly of the hydrodynamical neutral line **38,** while the discharge air flow **56** through the rotor balde runs outwardly of the hydrodynamical neutral line **38.** The position of the hydrodynamical neutral line **30** will be shifted depending on the configuration of the air chamber **24** and those of the rotor blades and may be expressed in the following formula:

$$PiAiVi = PoAoVo \ldots \quad (1)$$

wherein P represents density, A does area, V does flow velocity, i does inlet, o does outlet. Thus, Ai represents an area defined by the rotor blades adjoining to each other and positioned inwardly of the hydrodynamical neutral line **38,** and Ao represents an area defined by the adjoining rotor blades **1** and positioned outwardly of the hydrodynamical neutral line **38.** As can be seen from the aforesaid formula, the flow velocity Vi of the suction air flow **55** is accelerated by the centrifugal force by means of the rotor blades **1** to a flow velocity Vo of the discharge air flow **56** and then discharged into the rotor body **7** through the rotor discharge area Ao, such that the flow velocity Vi varies depending on the accelerating condition of the fluid, i.e., the R.P.M. of rotor and the ratio of inner and outer circumferences **43** and **44** of the rotor.

If the thickness of the tip portion of the rotor blade **1** is increased, there will result a decreased discharge area Ao, with the result that the hydrodynamical neutral line will be shifted toward the inner circumference of the rotor. It is apparent in view of the relationship of $Vi < Vo$, that the hydrodynamical neutral line is positioned outwardly of the center line dividing the suction area Ai and the discharge area Ao, equally. As the R.P.M. increases, the discharge velocity Vo will then be increased from the suction velocity, such that the position of the hydrodynamical neutral line will be further shifted outwardly of the center line immediately described above.

According to the important aspect of the invention, the contours of edge faces **1a** of the rotor blades will be determined commensurate to the air flows of opposite directions and sides with respect to the hydrodynamical neutral line.

FIGS. **6** and **7** show the contours of the rotor blades embodying the present invention. In terms of the rotational direction of the rotor body **2** as shown at **28,** the respective cross sectional views taken along the lines VII*a* to VII*e* of FIG. **6** are shown in FIG. 7*a* to 7*e*. the VII*a* cross section of the rotor blade is cut at the right upper edge thereof to a greater radius of curvature, while the VII*b* cross section of the rotor is cut at the right upper edge thereof to a smaller radius of curvature. The VII*d* cross section of the rotor past the VII*c* neutral cross section on the hydrodynamical neutral line **38** is cut at the left upper edge thereof to a smaller radius of curvature, while the VII*e* cross section is cut to a greater radius of curvature. In this respect, the curvatures thus provided are varied continuously. FIG. **8** shows the appearance of the rotor blade. The cross-sectional contours of the rotor blades are so designed as to minimize the development of the wake in the strip stream or in the rear of the rotor blade **1.** As is clear from the comparison of FIG. **9** with FIG. **10,** the smaller the thickness of the rotor blade, the lesser will be the effect of the wake **30.** However, the thickness of the rotor blade should be subject to some limitation arising from the strength requirement and ease in manufacture of the rotor blade **1.** The contour of a rotor blade **1** as shown in FIG. **11** which accommodates the air flow within the vortex blower may presents the same effect as that given by the rotor blade having thickness lesser than required, thus minimizing the effect of the wake. For determining the contour of a rotor blade, it is imperative to be accurately familialized with the air flow within the vortex blower. The embodiments as shown in FIG. **7** are so determined of its contour based on the experimental data of the absolute velocity of the air within the blower and the direction of the air flow. More specifically, FIG. **12** shows cross sectional view taken along the line XII — XII of FIG. **1,** in which a vector triangle **41** is described by using the absolute velocity **39** of the air flowing from the air chamber **24** to the air passage **21** or flowing in the reversed direction thereto, and by using the peripheral velocity **40** of the rotor body **2,** thereby obtaining the velocity of the air relative to the rotor body **2.** FIG. **13** shows one example of the measurements, illustrating as ordinary the radial distance from the inner circumference of the air chamber **24** as shown in FIG. **6** to the outer circumference **44** thereof, while illustrating as abscissa the angle α formed by the peripheral velocity **40** with the relative velocity **42** of the vector triangle. The positive angle α denotes that air flows from the air chamber **24** to the air passage **21,** while the negative angle α denotes that the air flows from the air passage **21** into the air chamber **24.** The aforesaid measurements were given over the range from the suction port **9** to the discharge port **22,** thereby obtaining the hydrodynamic neutral line **38,** i.e., the point at which the direction of the air flow is reversed. The contour of a rotor blade according to the present invention and shown in FIGS. 7*a* to 7*e* is determined in a manner that the air outward of the hydrodynamical neutral line **38** thus determined flows from the air chamber **24** into the air passage **21,** and the air inward of the aforesaid neutral line **38** flows from the air passage **21** into the air chamber **24** but commensurate to the angle α. The hydrodynamical neutral line **38** includes so-called hydrodynamic neutral points and thus may be shifted depending on varying factors. It is preferable that the contour of the rotor blade, as shown in FIG. **8,** includes the portion, where the inclined portion **51** of the suction portion and the inclined portion **52** of the discharge portion may be co-existent. The plane of the rotor blade flush with the rotor plane consists of the edge portion **49** on the suction side, the neutral portion **48** and the edge portion **50** on the discharge side. The width of the edge portion should preferably be minimized, but in the range corresponding to 10 to 30 percent of the thickness of the blade, from viewpoints of the ease in the actual finishing operation.

Meanwhile, the thickness of the blade in the vicinity of the hydrodynamical neutral line is somewhat greater than other portions, because of the small degree of the inclination of the blade. However, this would not affect the characteristics of the blower to an appreciable degree, presenting no problem.

Meanwhile, since the hydrodynamic center is positioned close to the outer circumference of the air chamber, the width of the inclined portion **52** on the discharge side may be small, when considering the variation in width with respect to the position of the aforesaid hydrodynamic point, such that the consideration may not be given to the width of the inclined portion **52** in the case of a small size blower, because of negligible difference in effect due to such considerations. On the other hand, the inclination of the same angle may be provided for the rotor blade over the range from its root to the outer circumferences of a rotor to obtain some degree of the effect.

The results of the characteristic test of the vortex blower incorporating rotor blades of contours according to the present invention are shown in FIG. **14** in comparison with those of the conventional type vortex blower. The vortex blower as shown in FIGS. **1** and **2** includes the air chamber having radius of **25** R, the outer diameter of rotor being 238 mm and the number of the rotor blade being **39.** As can be seen from the drawings, the blower according to the present invention presents the discharge pressure about 40 percent greater and the maximum internal efficiency about 7 percent greater than those of the conventional. In the embodiments of the invention as shown herein, the tip portion of the rotor blade alone is contoured so as to accommodate or to be streamlined to the air flow, but the rotor blade in its entirety may be contoured for the aforesaid purpose to further improve the characteristics of the vortex blower.

As shown in FIG. **5,** the directions of the circulating flow are reversed depending on the suction side and discharge side of the rotor grooves or compartments **23** and varied even on the suction side or the discharge side, alone. However, the edge face 1a of the rotor blade as shown in FIG. **15,** may be cut to an angle of θ throughout the edge fact thereof in a direction in agreement with the average direction of the circulating flow, thus obtaining relatively excellent effect. The optimum degree of an angle may be varied with the change in the specification of the blower, such as size of the impeller groove portion, spacing of blades, etc. According to the experiments, it is preferred that $\theta =$ 30 to 75°. Even if the angle θ exceeds 75°, there may result a relatively high discharge pressure, while such an angle is considered to be impractical in view of the strength requirement and ease in machining, because the reduced thickness of the blade will result. Conversely, if the thickness of the blade is increased, then the effective area of the flow passage will be decreased, with the accompanied greater loss.

Under such considerations, the height h and the width t and the angle θ of the blade may be determined according to the following formula (see FIG. **15**);

$$h = h' + \frac{t}{\tan(90° - \theta)}, \quad h' \geqq 61, \quad \theta = 30° - 75°.$$

With the conventional type, i.e., in case angle $\theta = 0$, the pressure coefficient ranges from 8 to 10, while the pressure coefficient may be increased to 16 to 17, if the edge faces of the blades are provided with inclination of an optimum angle.

On the other hand, depending on the size, thickness and height of a blade, the edge face of a blade may be free of inclination as shown in FIG. **16** or **17,** or the entire inclined face may be substituted by a curved surface. On the other hand, for the convenience of machining, the edge face of the blade may be provided with a small degree of inclination so as to render the upper edge side of the blade smaller or, the edge portions thereof may be rounded.

On the other hand, the blade may be inclined in its entirety with respect to the opening surface of an impellers, in an attempt to reduce the loss in flow and improve the characteristics of the blower, while presenting difficulties in machining and higher cost than the other type of blowers.

What is claimed is:

1. A vortex blower consisting of a stator body including an air passage having a suction port and a discharge port open thereto in the vicinity of the opposite ends of said passage and a rotor body having an air chamber divided into compartments by a plurality of rotor blades, in which the edge faces of the rotor blades in the vicinity of the inner circumference thereof is inclined rearwardly with respect to the rotational direction of said rotor body, the edge face of a rotor blade covering from the inner circumference to the outer circumference of said blade being so inclined that the height of the blade at the trailing edge of said edge face with respect to the rotational direction of the rotor is greater than that of the blade at the leading edge of said edge face.

* * * * *