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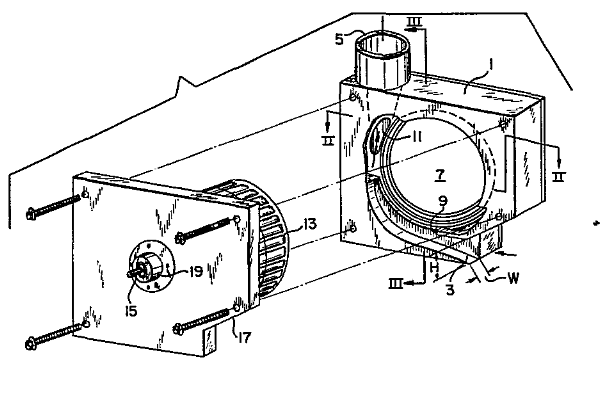
(54) Air-powered motor and a rotor therefor.

(57) The present invention is directed to an air-powered motor and a turbine rotor therefor which can be used to drive small power tools, such as a vacuum cleaner floor tool, a sander or a grinder, and in which the motor can be coupled to a household vacuum cleaner to provide a source of vacuum or forced air to drive the turbine rotor. The turbine rotor has a structure which substantially increases the efficiency of the motor as compared to prior art devices and, in particular, the motor comprises a housing having a turbine chamber, an air inlet and an air outlet. The turbine rotor is rotatably mounted in the chamber, the turbine rotor having a plurality of turbine blades extending from the outer surface of the rotor towards the interior thereof. A plurality of turbine buckets are formed in the rotor, the top and bottom of the buckets being formed by a semi-circular wall. The structural elements which form the buckets are positioned with respect to one another such that the bucket angle of the bucket $\beta \leqq 60°$, the bucket radius ratio $\frac{R_O - R_B}{R_O} \leqq 0.44$ and the blade inlet angle $\alpha \leqq 27°$. Furthermore, the turbine rotor is balanced to further enhance the efficiency of the motor.



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AN AIR-POWERED MOTOR AND A ROTOR THEREFOR

The present invention is directed to an air-powered motor and a rotor therefor and, in particular, to an air-powered motor and rotor therefor which can be used to drive small power tools, such as a floor tool for a vacuum cleaner, a sander or a grinder, wherein the air-powered motor uses a source of power such as a vacuum cleaner.

Prior art air-powered motors, driven by a vacuum cleaner, for example, are known in the art, such as those shown in U.S. Patent 2,963,270, U.S. Patent 2,962,748 (which is a CIP of U.S. Patent 2,963,270), and U.S. Patent 3,005,224. Yet another example of such a device is shown in U.S. Patent 3,004,100. These prior art devices have turbines which comprise a housing, which forms the turbine chamber and a rotor rotatably mounted within the chamber. The rotor includes a plurality of blades mounted between two side members, the blades and the side members forming turbine buckets which are open on the periphery of the rotor and are closed at their rear ends by a bottom wall member. This rear wall member may be semi-circular, as is illustrated in U.S. Patent 2,963,270.

In these prior are devices, the rotors have been constructed without consideration of characteristics such as bucket angle, bucket radius ratio, blade inlet angle, and dynamic balancing, which are significant factors which affect the motor efficiency. The operation of the prior art devices, espec. known floor tools is unsatisfactory because the turbine motor does not generate enough power to drive a rotary brush to which it is coupled in order for the rotary brush to properly perform. A known floor tool has a bucket angle $\beta = 82^0$, a rotor blade ratio $\frac{R_0-R_B}{R_0} = 0.604$ and a blade inlet angle $\alpha = 39^0$. This unit has an efficiency of 35%.

Another commercially available unit, also a floor tool, has a bucket angle $\beta = 67.5^0$, a bucket radius ratio $\frac{R_0-R_B}{R_0} = 0.60$, and a blade inlet angle $\alpha = 30^0$. This unit has an efficiency of 25%.

Tangential buckets are old in large turbines, as shown in U.S. Patent 966,157. The design considerations in these prior art large turbines are very different from the present invention because of the size considerations, and these prior art large turbines do not have the structural relationships between elements as in the present invention.

It is the primary object of the present invention to provide an air-powered motor and a turbine rotor therefor in which the turbine buckets of the rotor have a structure which significantly enhances the efficiency of the air-powered motor.

It is another object of the present invention to provide an air-powered motor and a turbine rotor therefor wherein the bucket angle of the turbine buckets is $\beta \leqq 60^{0}$.

It is still another object of the present invention to provide an air-powered motor and a turbine rotor therefor in which the radius ratio of the turbine buckets is $\frac{R_0 - R_B}{R_0} \leqq 0.44$.

It is a further object of the present invention to provide an air-powered motor and a turbine rotor therefor wherein the blade inlet angle $\alpha \leqq 27^{0}$.

It is still another object of the present invention to provide an air-powered motor and a turbine rotor therefor wherein the turbine rotor is dynamically balanced about its rotational axis.

It is still a further object of the present invention to provide an air -powered motor and a turbine rotor therefor which can be driven by a vacuum source, such as a vacuum cleaner, the air-powered motor being used to drive small power tools, such as a vacuum cleaner floor tool, a sander or a grinder.

It is still another object of the present invention to provide an air-powered motor and turbine rotor therefor wherein several tools which incorporate such motors can be driven by a single vacuum cleaner.

It is still a further object of the present invention to provide an air-powered motor and rotor therefor which is inexpensive, light-weight and simple to manufacture.

The present invention is directed to an air-powered motor and a turbine rotor therefor which can be used to drive small power tools, such as a vacuum cleaner floor tool, a sander or a grinder, and in which the motor can be coupled to a vacuum cleaner to provide a source of vacuum or forced air to drive the turbine rotor. The turbine rotor has a structure which substantially increases the efficiency of the motor as compared to prior art devices and, in particular, the motor comprises a housing having a turbine chamber, an air inlet and an air outlet. The turbine rotor is rotatably mounted in the chamber, the turbine rotor having a plurality of turbine blades extending from the outer surface of the rotor towards the interior thereof. A plurality of turbine buckets are formed in the rotor, the top and bottom of the buckets being formed by the turbine blades, the sides of the buckets being formed by the sides of the rotor and the rear wall or bottom of the buckets being formed by a semicircular wall. The structural elements which form the buckets are positioned with respect to one another such that the bucket angle of the bucket $\beta \leqq 60^{\circ}$, the bucket radius $\frac{R_0 - R_B}{R_0} \leqq 0.44$ and the blade inlet angle $\alpha \leqq 27^{\circ}$. Furthermore, the turbine rotor is dynamically balanced about its rotational axis to further enhance the efficiency of the motor.

Figure 1 is an exploded perspective view of an air-powered motor of the preferred embodiment of the present invention.

Figure 2 is a sectional view through section II-II of Figure 1;

Figure 2A is a sectional view through section II-II of Figure 1 with a turbine rotor in the housing;

Figure 3 is a sectional view through section III-III of Figure 1;

Figure 3A is a sectional view through section III-III of Figure 1 with a turbine rotor in the housing;

Figure 4 is a perspective view of the turbine housing of the present invention;

Figure 5A is a side view of a turbine rotor of the preferred embodiment of the present invention;

Figure 5B is a partial side view of a turbine rotor of the present invention;

Figure 5C is a partial side view of a turbine rotor and the turbine housing of the present invention;

Figure 6 is a diagram illustrating the derivation of the blade inlet angle;

Figure 7 is a section through a turbine bucket and nozzle of the present invention;

Figures 8A-8F are schematic diagrams illustrating the flow of air through the turbine rotor of the present invention;

Figure 9 is a graph illustrating the performance characteristics of an air-powered motor of the present invention;

Figure 10 is a graph illustrating the operating range of power sources used to drive an air-powered motor of the present invention.

Referring to the drawings, the air-powered motor of the present invention includes a housing 1 which has an air inlet in the form of a nozzle 3, the nozzle has a constant width W and a decreasing height H. The housing further includes an air outlet 5 which may be connected to a source of vacuum 6, such as a vacuum cleaner. Alternatively, a source of forced air 8, such as a fan or vacuum cleaner exhaust, can be connected to the air inlet 3 of the housing. The centers of the air inlet and the air outlet are offset with respect to one another. A turbine chamber 7 is formed within the housing 1, and air enters the turbine chamber 7 through nozzle opening 9 and exits therefrom through port 11 of the air outlet 5. Turbine rotor 13 is positioned within the turbine chamber 7 in the housing 1, the turbine rotor 13 being rotatably mounted on shaft 15, which is supported on bearing 19 in the wall 17 of housing 1. The shaft 15 passes through the center of rotor 13 and may extend from the other side thereof, and be supported by a suitable bearing structure (not shown) in wall 21 of housing 1. Shaft 15 is coupled to a tool or other device 10, which the motor drives by means of the rotation of shaft 15.

Referring to Figures 5A, 5B and 5C, rotor 13 includes a plurality of turbine blades 23 which extend inwardly from the rotor periphery 25. Adjacent blades are connected together by means of rear walls or bottoms 27. The turbine blades 23, rear walls 27 and the sides 29 of the rotor 13 form a plurality of turbine buckets which are open at their top and are positioned around the periphery of the turbine rotor 13.

Referring to Figure 5B, point 31 is located on rear wall 27 at a point equidistant between adjacent blades 23. Point 33 is located on the periphery of the turbine rotor at a point midway between the tips of the adjacent rotor blades 23. A line 35 is drawn between these two points, and a line 37 is drawn tangential to the periphery of the rotor 13 at the point at which line 35 intersects the periphery. The angle between lines 35 and 37 is defined as the bucket angle β . The bucket angle $\beta \leqq 60^{0}$.

The bucket angle β is significant in that it is related to the tangential nature of the turbine blades. Since radial air flow into buckets does not perform any useful work in the sense of rotating the bucket and,in fact, has an adverse effect on performance in that is creates drag, the forming of buckets which are tangential in nature is a significant factor in enhancing the efficiency of the motor and thus is a critical factor in the turbine bucket strcture.

R_0 is the radius from the center of the turbine rotor to the periphery thereof, and R_B is the radius from the center of the turbine bucket to the point 38 which is the innermost point of the interior of the bucket. The turbine bucket radius ratio is defined as $\frac{R_0-R_B}{R_0}$. The turbine bucket radius ratio $\frac{R_0-R_B}{R_0} \leqq 0.44$.

The radius ratio $\frac{R_0-R_B}{R_0}$ is also significant in that it is also related to the tangential nature of the turbine blades. Since radial air flow into the buckets does not perform any useful work in the sense or rotating the bucket and in fact, has an adverse effect on performance in that it creates drag, the forming of buckets which are tangential in nature is a significant factor in enhancing the efficiency of the motor and thus is a critical factor in the turbine bucket structure. For optimum efficiency, the turbine buckets should be tangential. However, in order to form the buckets in a rotor for use in an air-powered motor for small power tools, it is necessary to provide some curvature to the buckets. The bucket angle β and the radius $\frac{R_0-R_B}{R_0}$ are significant factors in defining the permisisible curvature.

Referring to Figure 5C, it can be seen that the turbine nozzle 3 has an inlet area A1 and an outlet area A2. Since the volume of air flowing into the nozzle through area A1 is the same as the volume of air flowing out of the nozzle through area A2, the ratio of the velocity of the air in V1 to the air out V2 is inversely proportional to the ratio of the area in A1 to the area out A2.

Figure 6 is a diagram for determining the blade inlet angle α of the turbine rotor blades. One leg of the triangle is proportional to the velocity V1 and the other leg of the triangle is proportional to the velocity V2. The nozzle angle θ is the angle formed by the hypotenuse of the triangle and the leg proportional to the velocity V1. Referring to Figure 9, it can be seen that maximum efficiency occurs as 1/2 of the maximum rotor speed. Thus, referring back to Figure 6, a second triangle is formed which defines the blade inlet angle α for optimizing the turbine motor efficiency. Referring back again to Figure 5B, the blade inlet angle α is defined by line 39 extending tangentially from the tip of the blade 23 and by line 41 which is tangent to the periphery of the rotor at the point at which line 39 intersects the rotor. The rotor is constructed so that the blade inlet angle α as defined in Figure 5B is that which optimizes efficiency in accordance with the determination made in Figure 6. Therefore, blade inlet angle $\alpha \leqq 27^{o}$ and is preferably in the range of $15^{o} \leqq \alpha \leqq 27^{o}$ the 15^{o} angle corresponding to the nozzle angle θ. The blade inlet angle is another critical factor which effects turbine efficiency.

Still another significant factor in enhancing the turbine efficiency is to provide a dynamically balanced turbine rotor. The rotor is dynamically balanced about its axis of rotation, thus being dynamically balanced in the circumferential direction to thereby maintain a constant output, reducing drag and enhancing overall reliability by eliminating wear at particular points resulting from an unbalanced rotor through a wide range of operating speeds. The maximum out-of-balance limit is 0.055 gram-centimeters.

The rear wall 27 of the turbine bucket should have a shape and relationship to nozzle width which optimizes efficiency. Applying the characteristics for fluid flow in ducts defined in <u>The General Electric Data Book, Heat Transfer and Fluid Flow</u>-, Section G 403.3, Curved Ducts of Uniform Cross Section-Turbulent Flow, pages 2 and 3, the centerline radius ratios between 1.0 and 7.5 provide minimal losses in square cross-section ducts. Assuming that the losses due to inlet air turning in the turbine buckets are related to the losses occuring in curved ducts, then the same range of centerline radius ratios would be applicable to the turbine rotor buckets. Therefore, referring to Figure 7, the bucket radius of curvature $R_{CB} = \frac{W}{2} + r$, where W it the width of the nozzle 3, and r is the centerline of air flow through the turbine bucket. Area 43 shown in Figure 7 is a dead air space. The absolute minimum losses are obtained with a centerline radius ratio R_{CB} = 2.80, however, in order to have a turbine width $W = 2R_{CB} + 2t$, where t equals the wall thickness of the side 29 of the turbine rotor 13, a bucket radius curvature R_{CB} = 1.25 was selected. This bucket radius of curvature sacrifices some losses, but provides a turbine width which gives the necessary compactness required for consumer appeal.

Because of the path of air flow through the bucket, the air inlet and air outlet are offset with respect to one another as shown in Figure 3A and further as shown in Figure 7.

Figures 8A-8F illustrate the flow of air through the turbine rotor 13 in relationship to the rotation of the turbine rotor. Since Figures 8A-8F are schematic in nature, the various elements have been designated with the letter "a". As can be seen from Figures 8A-8F, air from nozzle 3a enters a bucket 29a and is turned through 180^{0} by the rear wall 27a. The momentum transferred from the flowing air to the rotor moves the bucket to the right as illustrated. Since the buckets are on the periphery of the turbine rotor, the movement of the bucket to the right causes a rotation of the rotor in the direction of arrow A.

Figure 9 is a graph showing the relationship of the torque on rotor 13 in relationship to the efficiency, power and speed of the turbine motor.

Figure 10 is a graph showing the limiting ranges of pressure and air flow performance characteristics of vacuum cleaners which are required in order to provide an adequate power source for the efficient operation of the air-powered motor of the present invention. Most commercially available vacuum cleaners can perform within the required operating range.

The present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The resently disclosed embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather that the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are, therefore, to be embraced therein.

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CLAIMS

1. An air-powered motor comprising a housing (1) having a turbine chamber (7), an air inlet (3) and an air outlet (5); a turbine rotor (13) rotatably mounted in said chamber (7), characterized in that said turbine rotor (13) having a plurality of turbine buckets wherein the bucket angle of each of said buckets is $\beta \leqq 60^{\circ}$; and a nozzle means (9) formed in said chamber (7) between said inlet opening (3) and said rotor (13) for directing air from said air inlet into the buckets of said rotor (13).

2. An air-powered motor as set forth in claim 1 wherein the radius ratio of said bucket $\frac{R_0 - R_B}{R_0} \leqq 0.44$.

3. An air-powered motor as set forth in any of claims 1 or 2 wherein the blade inlet angle of each of said buckets $\alpha \leqq 27^{\circ}$.

4. An air-powered motor as set forth in claim 3 wherein $15^{\circ} \leqq \alpha \leqq 27^{\circ}$.

5. An air-powered motor as set forth in any of claims 1 or 2 wherein said air inlet (3) and said air

outlet (5) are offset from one another with respect to the bucket opening.

6. An air-powered motor as set forth in any of claims 1 or 2 wherein said turbine rotor (13) is dynamically balanced about its axis of rotation.

7. An air-powered motor as set forth in claim 1 wherein the width of said nozzle (3) is less than, or equal to, 1/2 the width of said rotor (13).

8. An air-powered motor for driving a tool as set forth in any of the preeding claims characterized by the turbine rotor means (13) including a shaft (15) aligned with the axis thereof, said rotor means (15) being rotatably mounted in said chamber (7) on said shaft (15), said shaft having an output portion means extending outside of said housing (1) for coupling said turbine rotor means to a tool (10), said turbine rotor means (13) further including turbine blades (23) extending from the peripheral surface of said rotor towards the interior thereof, and a plurality of turbine buckets formed in said rotor (13), wherein the top and bottom of said bucket is formed by adjacent turbine blades (23), the sides of each bucket are formed by the sides (29) of the turbine rotor, and the bottom of each bucket is formed by a wall (27) extending between the ends of said turbine blades (23);

a nozzle means (9) formed in said chamber (7) between said inlet opening (3) and said turbine rotor means (13) for directing air from said air inlet into said buckets;

wherein air flows into said air inlet, through said nozzle (9), into said bucket, and against the bottom (27) thereof, and then out of said bucket in the opposite direction, and then into said chamber (7) and out of said air outlet (5), thereby rotating said turbine rotor means (13) whereby the output portion means of said shaft is rotated for driving a tool.

9. An air-powered motor as set forth in claim 8 wherein said air power source is a means coupled to said air inlet (3) for driving air through said air inlet.

10. A turbine rotor (13) for use in an air-powered motor according to one of the preeding claims, characterized by

a) a pair of parallel circular side walls (29);
b) a plurality of turbine blades (23) extending between said side walls (29);
c) wall means (27) extending between said side walls (29) and between adjacent turbine blades (23), wherein side walls, turbine blades and wall means form a plurality of buckets in said rotor having open ends positioned around the periphery of the rotor (13) and wherein the bucket angle of said buckets is $\beta \leqq 60^0$;
d) the said wall means (27) is semicircular.

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FIG. 1

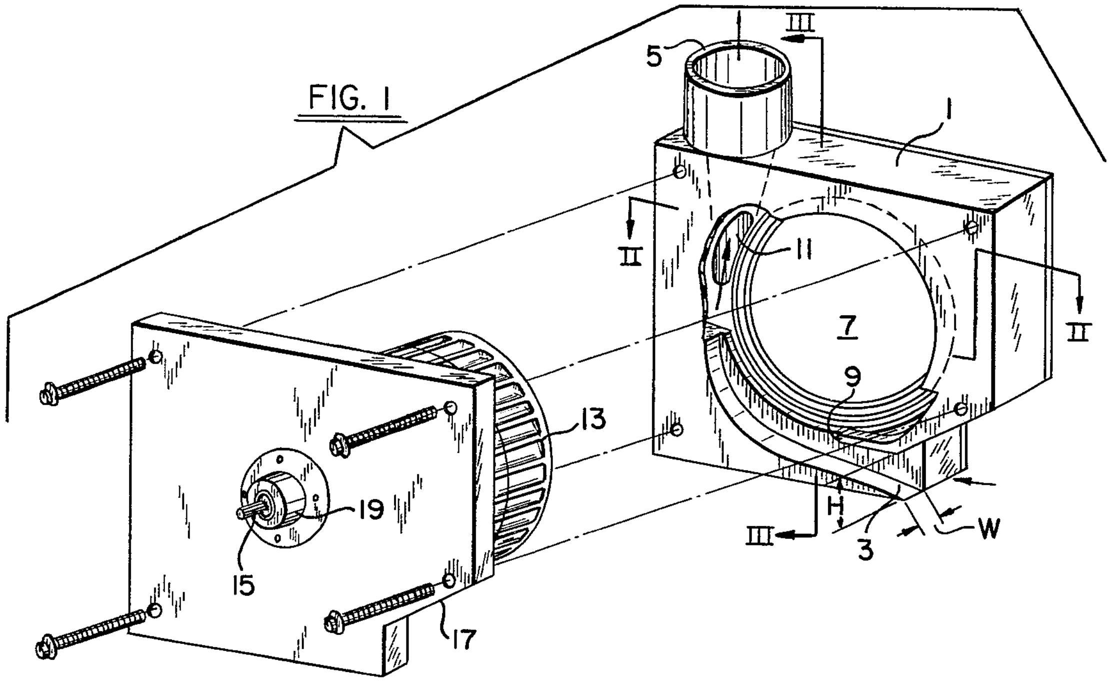


FIG. 2

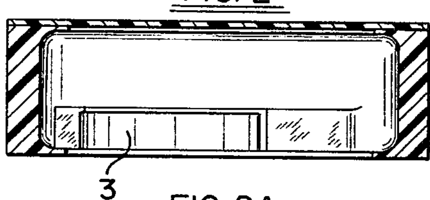


FIG. 2A

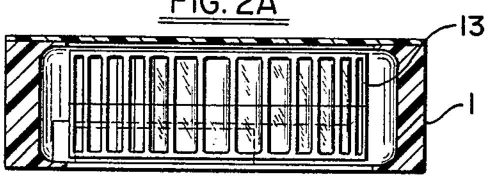


FIG. 3

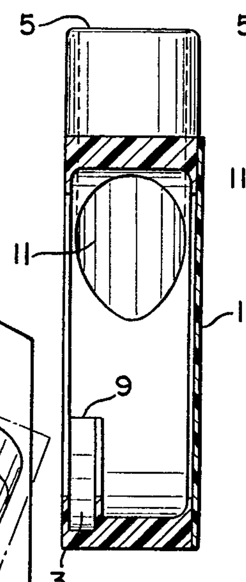
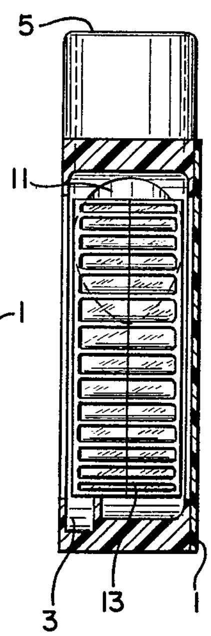


FIG. 3A



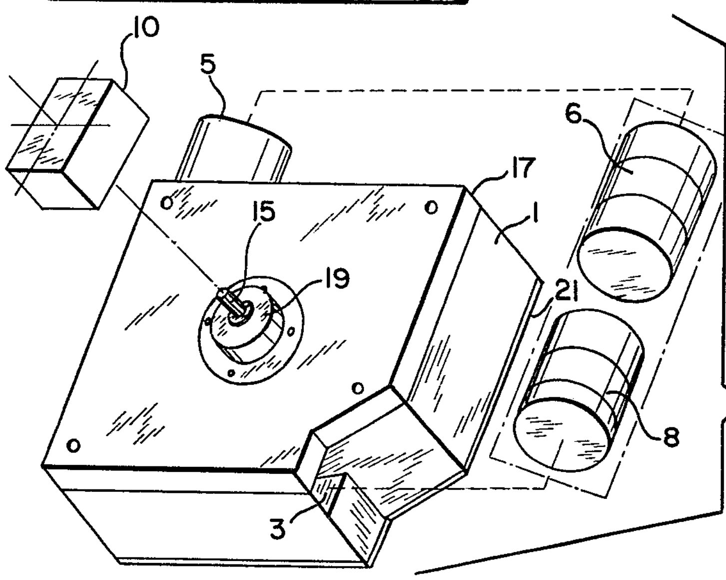


FIG. 4

FIG. 7

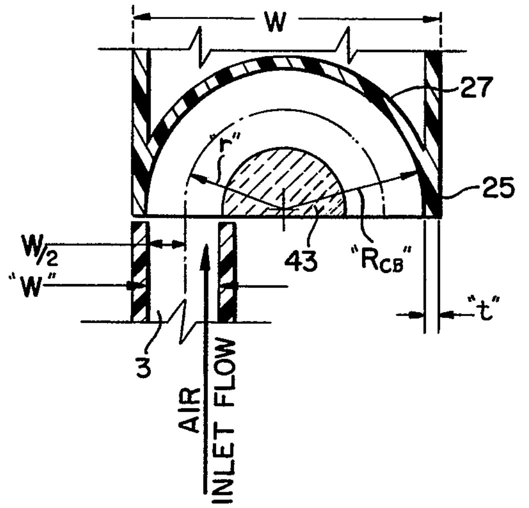


FIG. 5A

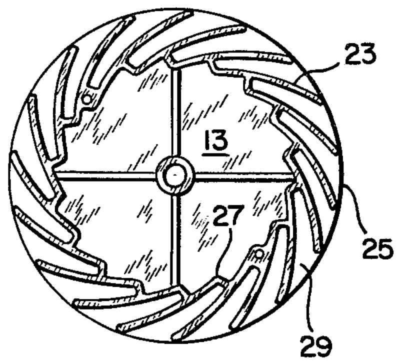
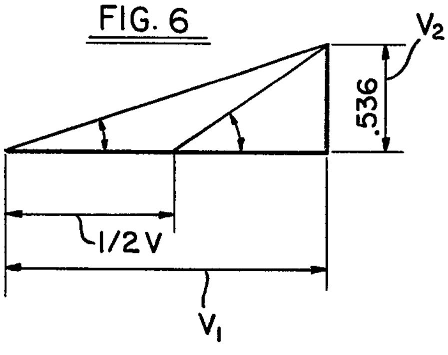


FIG. 6



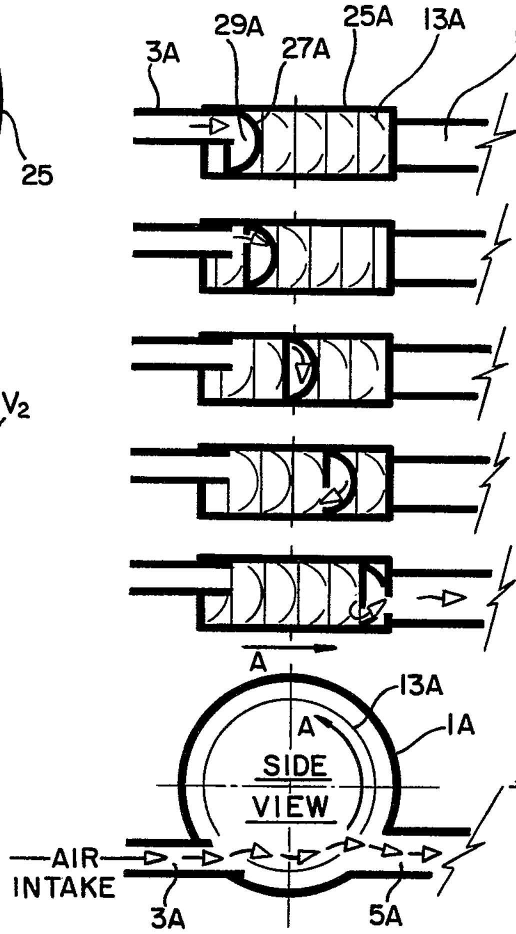


FIG. 8A

FIG. 8B

FIG. 8C

FIG. 8D

FIG. 8E

FIG. 8F

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FIG. 5B

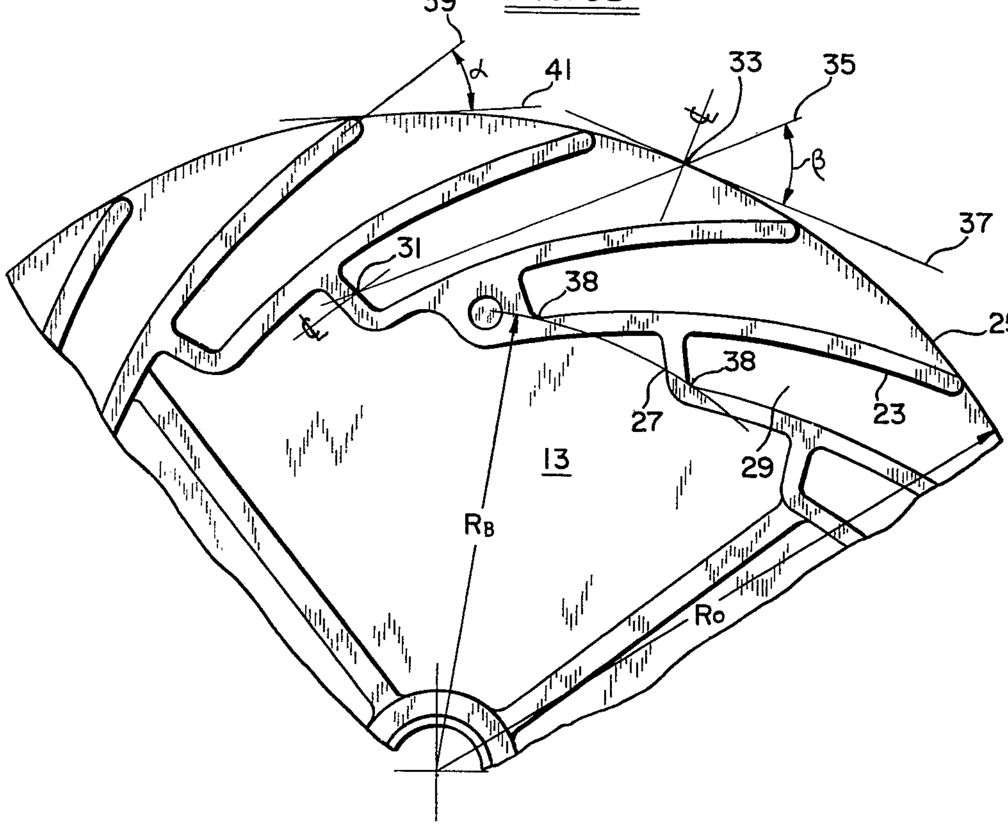
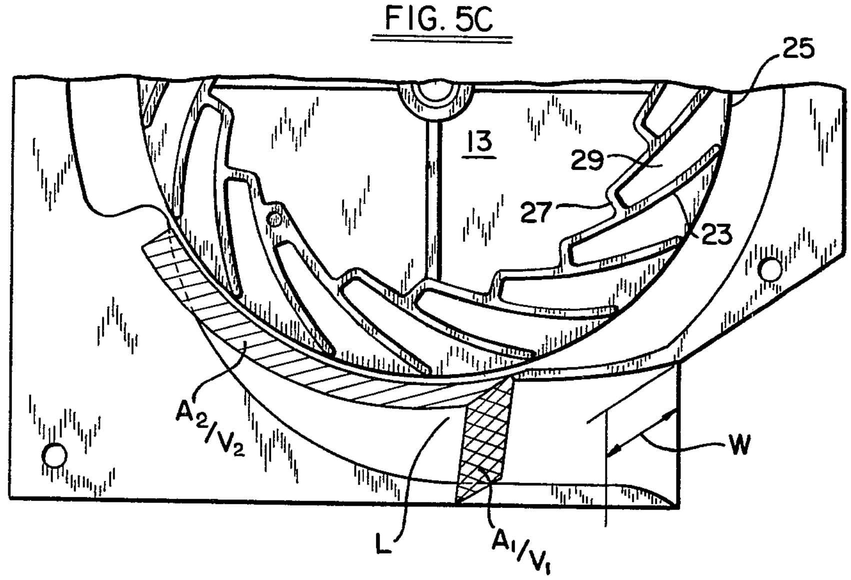


FIG. 5C



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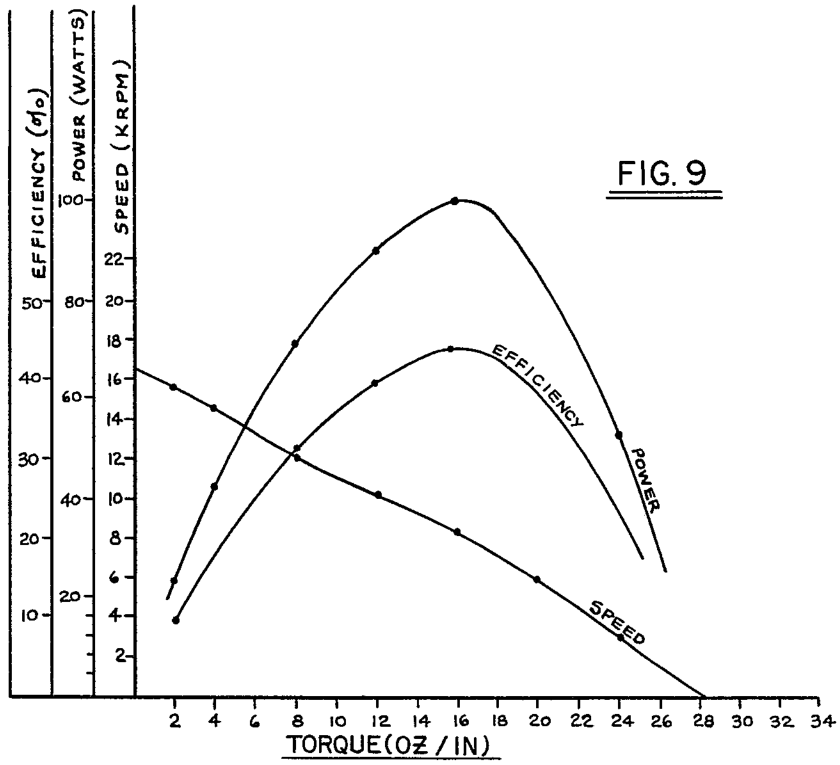

FIG. 9

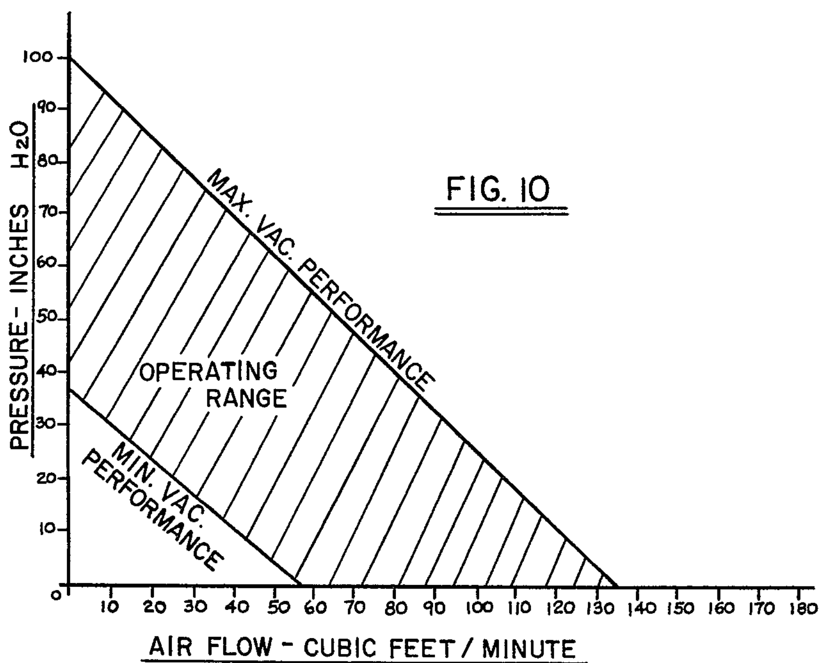

FIG. 10

European Patent Office

EUROPEAN SEARCH REPORT

0021435

Application number
EP 80 10 3826

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
	DE - A - 2 203 284 (KLAUS) * In its entirety * --	1-3
	DE - A - 2 746 202 (HEINRICH) * In its entirety * --	1,5,8,9
	FR - A - 1 103 927 (ECK) * Page 1, left-hand column, two last lines; right-hand column, lines 1-7, 29-39 * --	1
	US - A - 4 014 625 (YAMAMOTO) * Column 6, lines 7-41 * --	1-4,6
D	US - A - 3 044 100 (ZAIDAN) * Column 2, line 54 - column 4, line 3 * --	1,6,8,10
D	US - A - 2 962 748 (PRECO INCORPORATED) * Column 1, line 66 - column 2, line 31; column 3, lines 3-43; figures 6,7 * ----	1,3,4,8,10

CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)

F 04 D 17/04
29/28
F 01 D 1/34
A 47 L 9/04

TECHNICAL FIELDS SEARCHED (Int.Cl. 3)

F 04 D
F 01 D
A 47 L

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	24-09-1980	BONVIN

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