Oct. 24, 1933. P. E. GOOD 1,931,692

CENTRIFUGAL BLOWING APPARATUS

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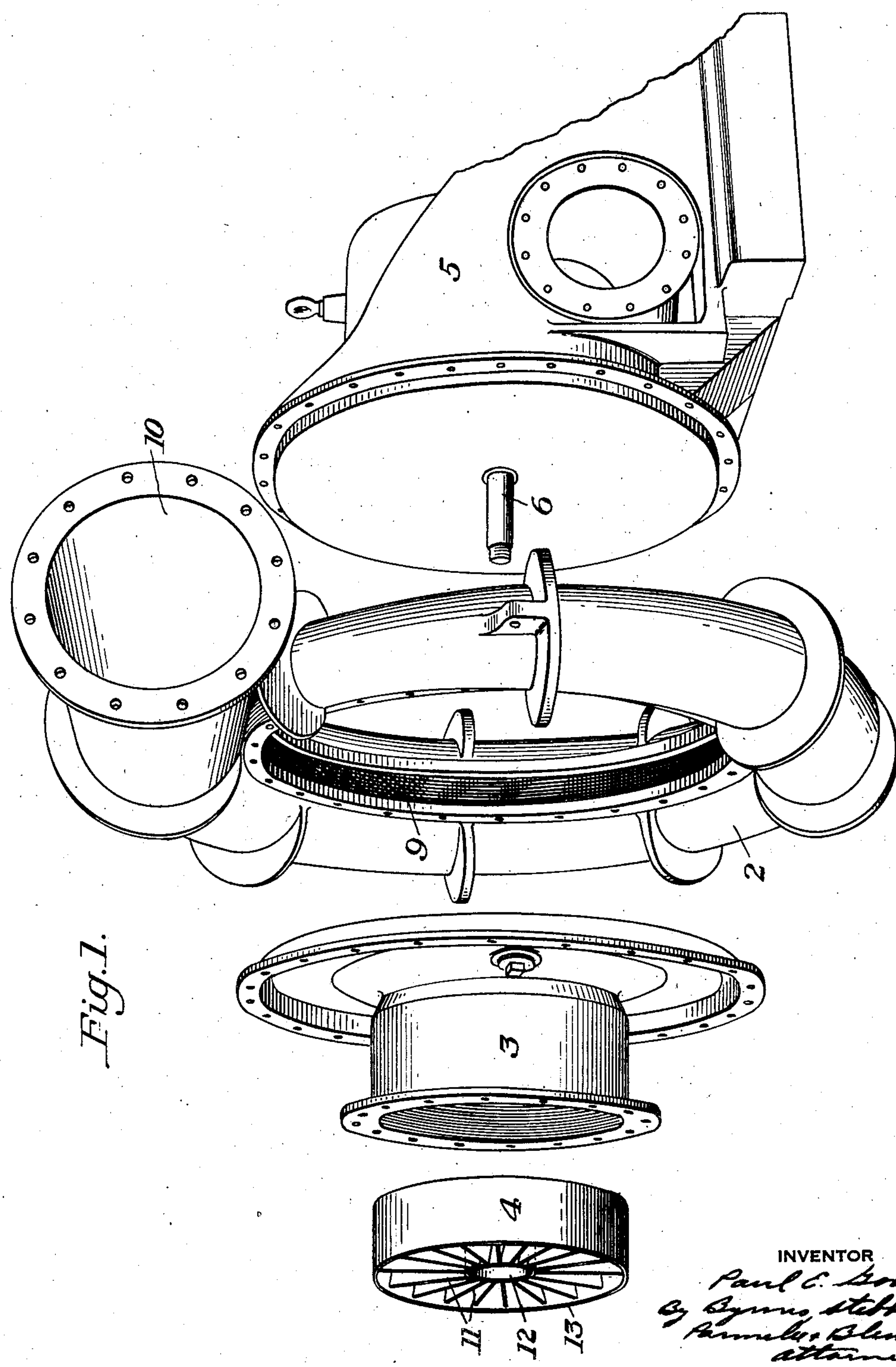

Fig. 1.

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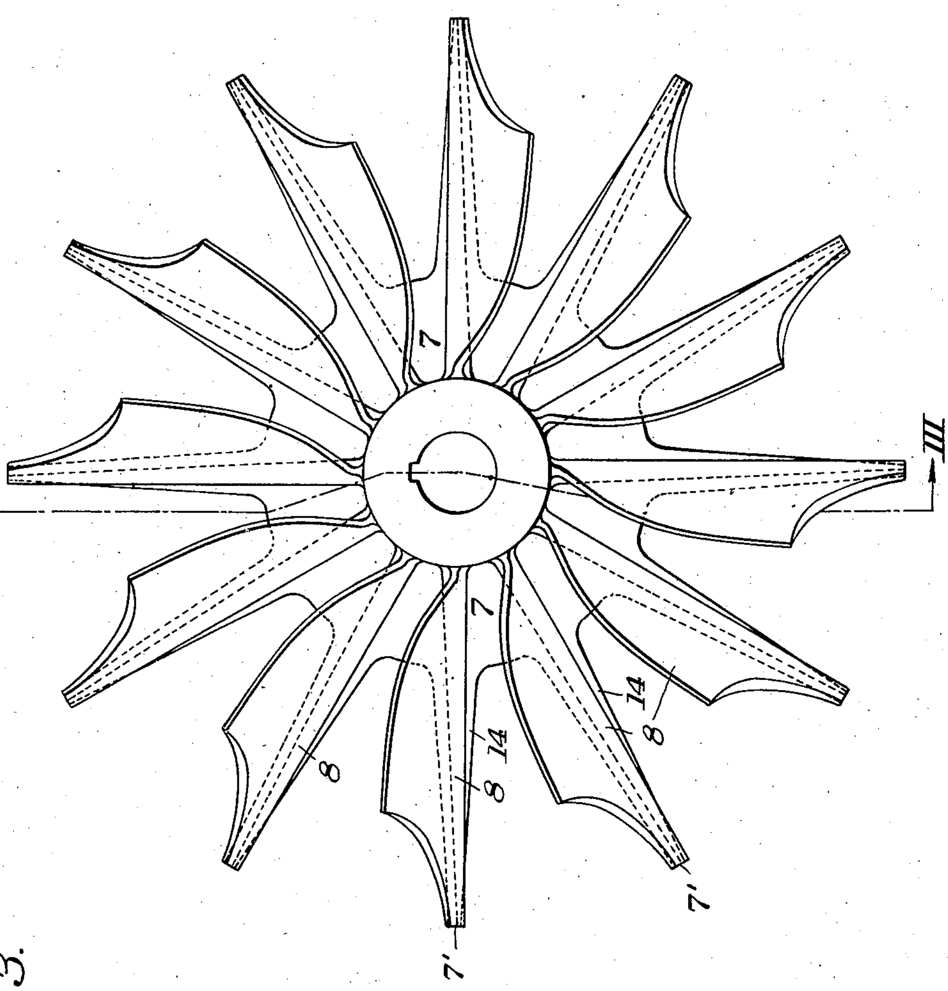
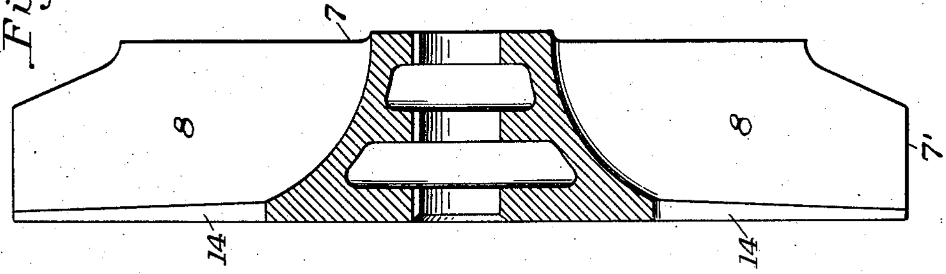


Fig. 2.

Fig. 3.



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CENTRIFUGAL BLOWING APPARATUS

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Fig. 4.

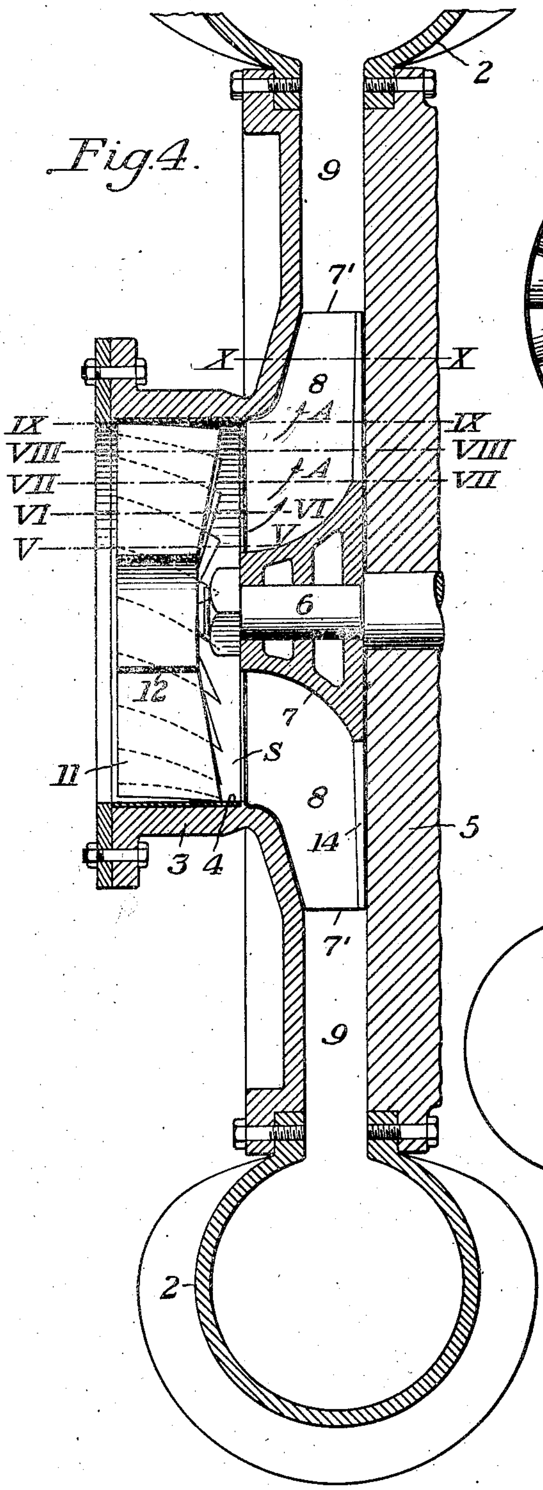

Fig. 14.

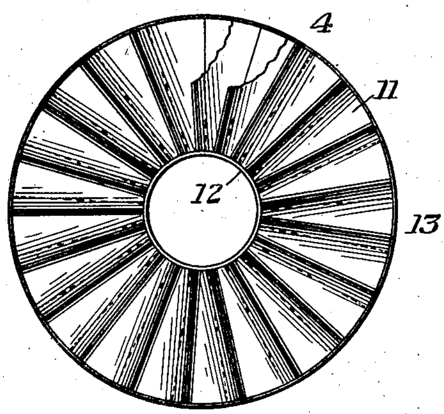

Fig. 15.

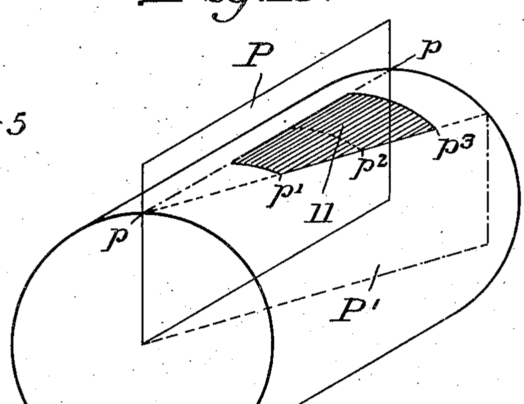

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Fig. 7.

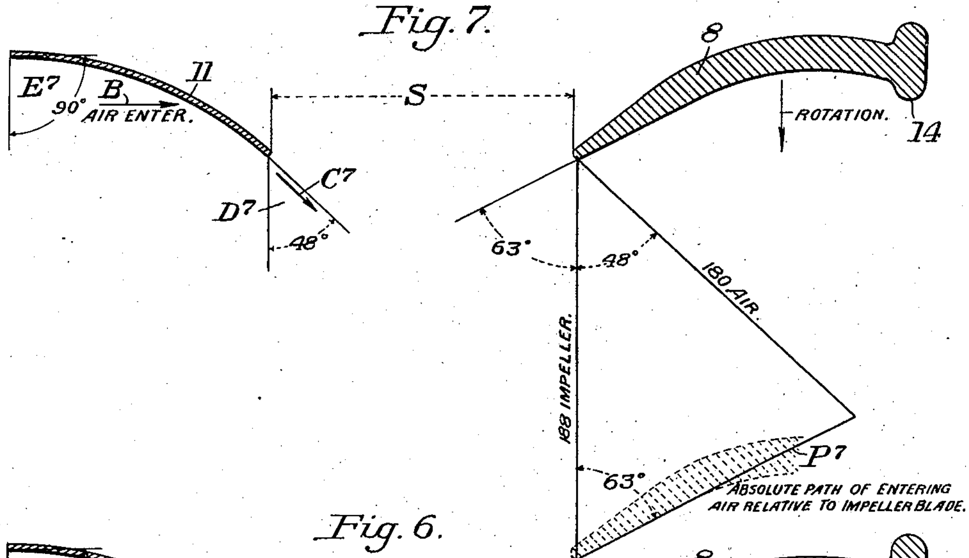


Fig. 6.

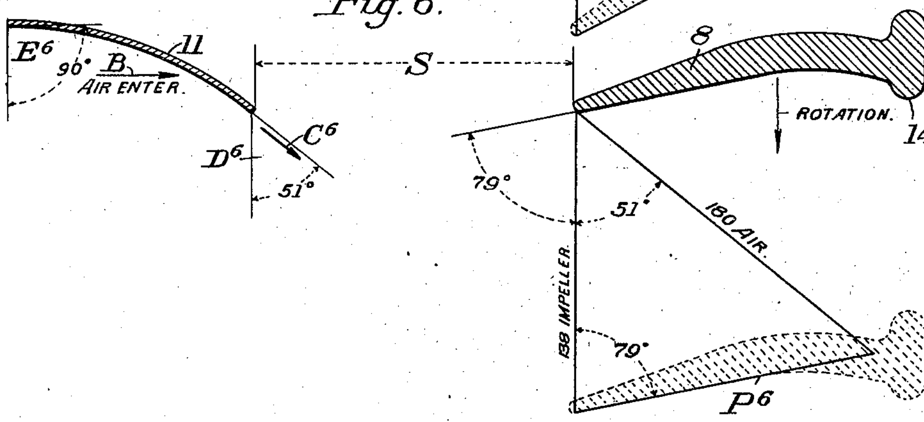
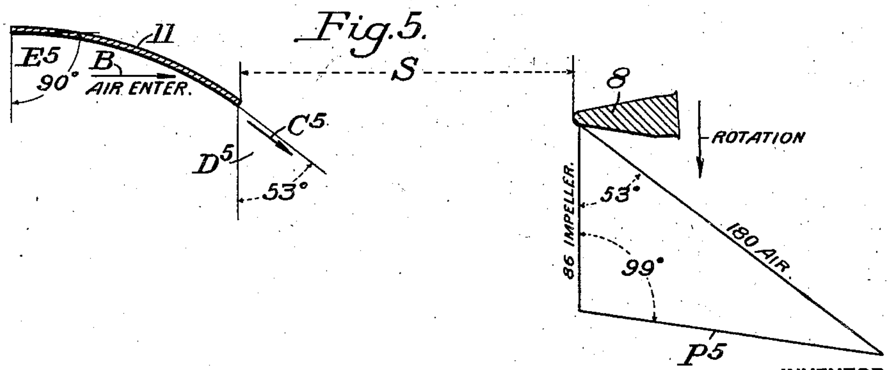


Fig. 5.



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CENTRIFUGAL BLOWING APPARATUS

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Fig. 9.

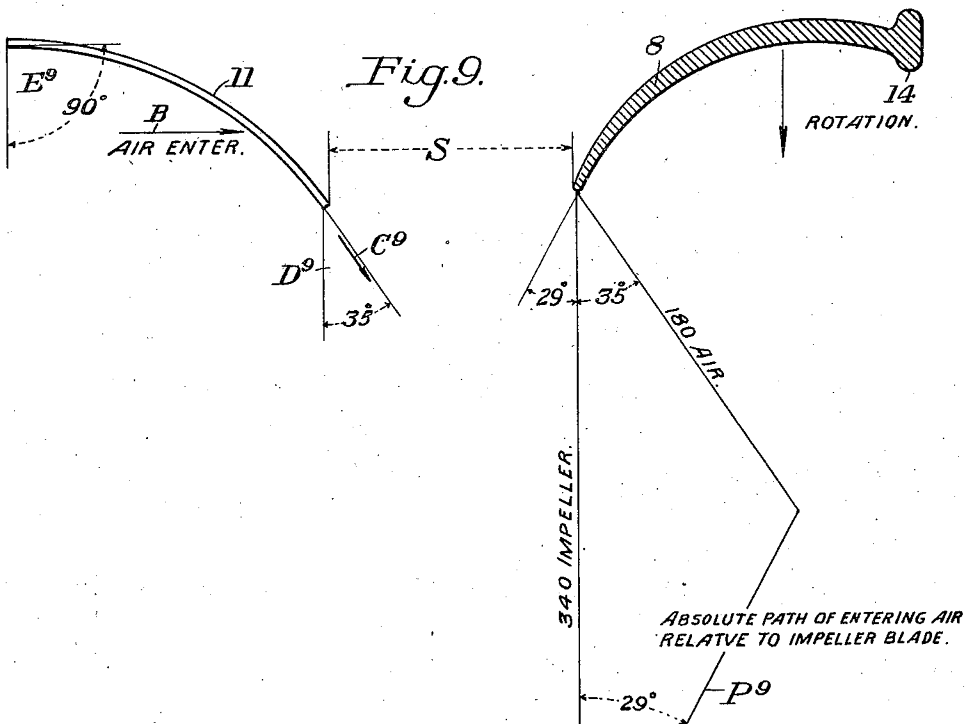

Fig. 8.

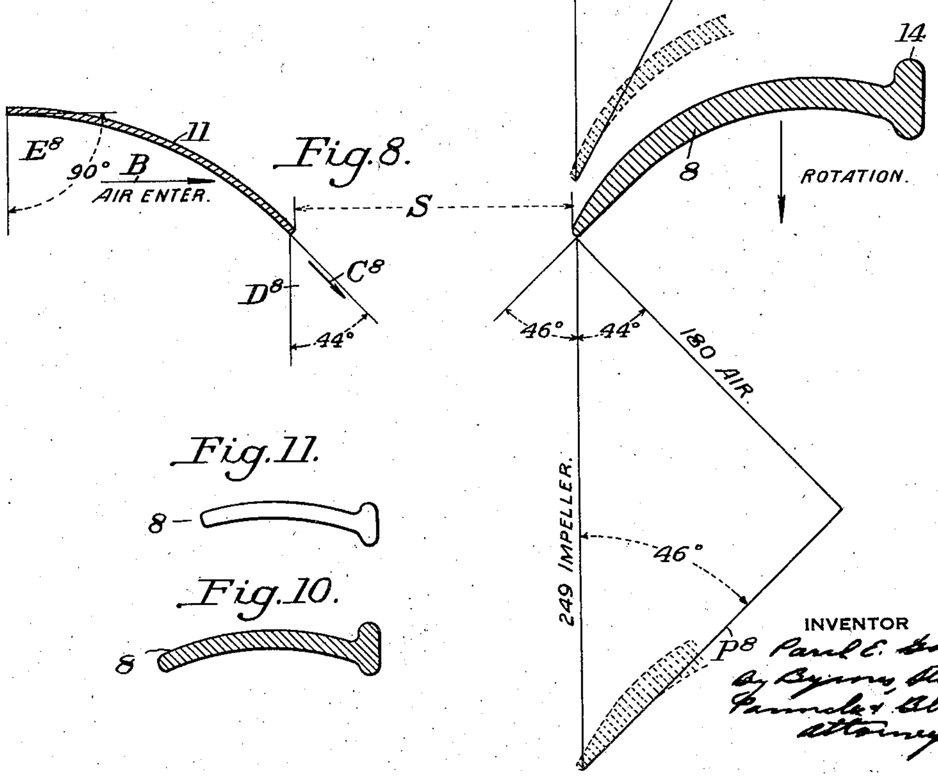

Fig. 11.

Fig. 10.

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Fig. 12.

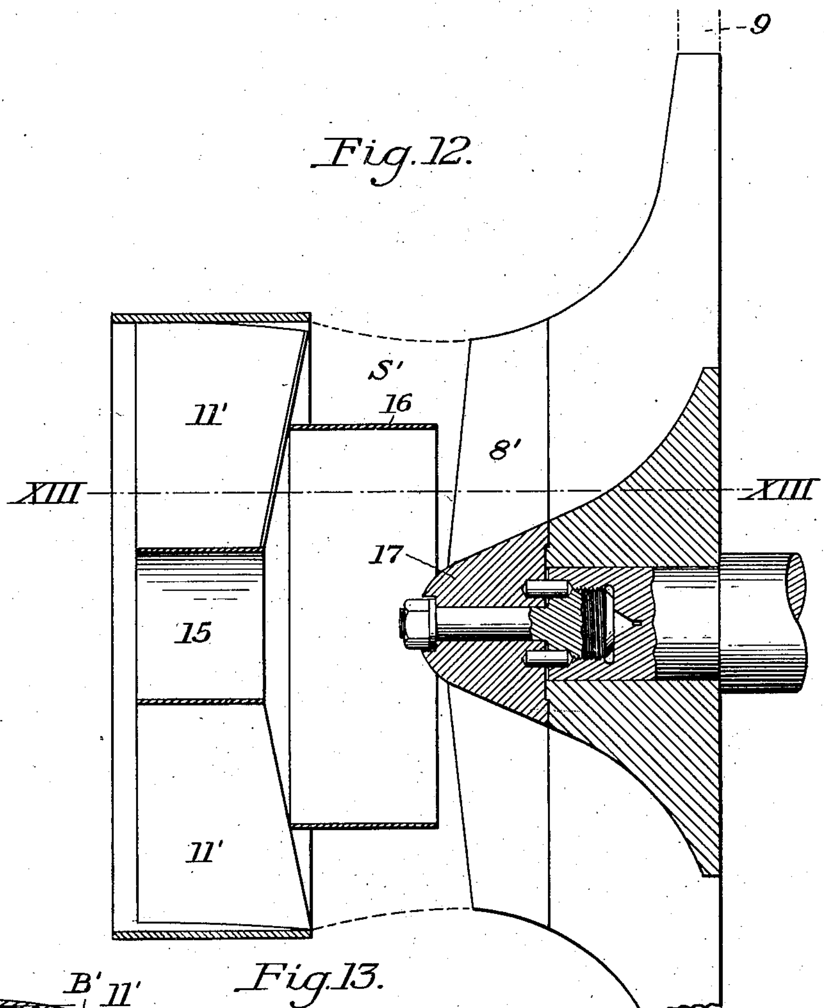
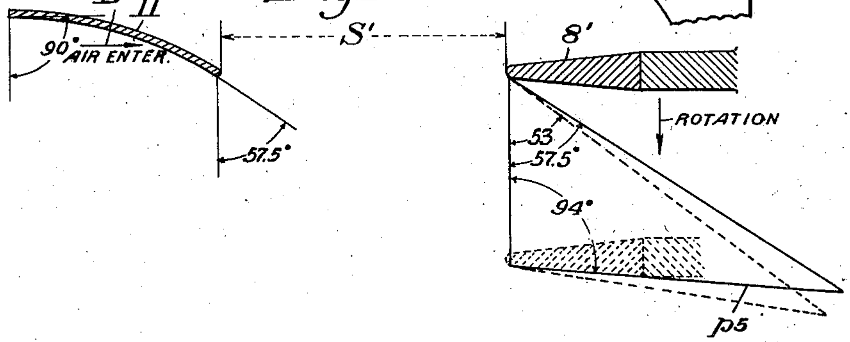


Fig. 13.



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Patented Oct. 24, 1933 **1,931,692**

UNITED STATES PATENT OFFICE

1,931,692

CENTRIFUGAL BLOWING APPARATUS

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Application February 15, 1930. Serial No. 428,698

15 Claims. (Cl. 230—127)

The present invention relates broadly to the art of fluid pressure apparatus and more particularly to a compressor of the type commonly referred to as a centrifugal blower, and utilized for compressing air and gases. In addition to improvements in the constructional characteristics of such apparatus, the present invention contemplates improvements in the method of determining such characteristics.

As is customary in the centrifugal blowing art, the present invention involves a housing of more or less " snail " shape, adapted to receive a positively driven impeller, by means of which the centrifugal blowing action is accomplished, together with an inlet connection having fluid directing vanes positioned therein.

The invention is embodied in a novel coordination of these various elements, and more particularly the impeller and vanes as well as in certain novel features of construction of the respective parts and the method of determining their proper contour or configuration.

The vane structure is so positioned as to produce a more or less axially directed flow of the fluid to be compressed into the impeller, the characteristics of the impeller and vanes being such as to produce the desired engaging action with a minimum shock, as between the entering air and the impeller.

In the accompanying drawings, I have shown for purposes of illustration only, certain preferred embodiments of the present invention.

In the drawings:

Figure 1 is an exploded perspective view illustrating the snail housing with an inlet casing and vane structure on one side and a portion of the impeller shaft housing on the opposite side, the impeller being removed for sake of clearness;

Figure 2 is a front elevational view of the impeller;

Figure 3 is a transverse sectional view on the line III—III of Figure 2;

Figure 4 is a view similar to Figure 3 illustrating the relationship of the vanes and impeller;

Figures 5, 6, 7, 8 and 9 are transverse sectional views on the lines V—V, VI—VI, VII—VII, VIII—VIII, and IX—IX of Figure 4, these views being more or less diagrammatic and having vector diagrams superimposed thereon;

Figure 10 is a transverse sectional view on the line X—X of Figure 4;

Figure 11 is an end elevational view of one of the blades;

Figure 12 is a view similar to Figure 4 illustrating a modified embodiment of the invention;

Figure 13 is a view similar to Figure 5 but taken on the line XIII—XIII of Figure 12;

Figure 14 is a perspective view of the vane structure; and

Figure 15 is a diagrammatic detail view illustrating the manner of forming the individual vanes.

Having reference more particularly to Figure 1 of the drawings, a blowing apparatus constructed in accordance with the present invention includes a snail housing 2 with one side of which cooperates an inlet casing 3, within which is carried a vane assembly 4. Cooperating with the opposite side of the housing 2 is a bearing 5 for an impeller shaft 6 adapted to receive an impeller 7, as illustrated in detail in Figures 2 and 3. Usually the bearing end 5 of the housing 2 will be the housing which contain the turbine or motor utilized for driving the impeller, and the bearings thereof will support the impeller shaft 6.

With the parts in assembled position, the ends 7' of the impeller blades 8 will rotate substantially in the plane of the inwardly directed opening 9, which opening in turn communicates with the discharge outlet 10.

Upon rotation of the impeller in the direction indicated in the drawings, air or other fluid being compressed will be drawn axially thereinto, as represented by the arrows A in Figure 4, these arrows being intended to illustrate direction of fluid flow and not relative distribution thereof.

As an actual matter of fact, the velocity of air over the entire area of the inlet casing 3 will not be constant. Since the lowest absolute pressure will exist nearest the hub of the impeller and the highest absolute pressure nearest the point of discharge of the impeller blades, there will be a varying pressure differential effective over the entrance to the inlet casing, which differential will be such as to produce the highest velocity of entering air adjacent the center of the casing, with a gradually decreasing velocity outwardly therefrom.

The fluid received by the impeller will first have been caused to pass axially through the inlet casing 3 wherein it will have been acted upon by the vanes 11 carried thereby. These vanes at their inner ends may cooperate with an inner ring 12 and at their outer ends with a similar ring 13 of larger diameter, the outer diameter of the ring 13 being substantially equal to the inner diameter of the casing 3 whereby the vane assembly may be axially inserted into or removed from the inlet casing. This construction is illustrated more particularly in Figures 4 and 14 of the drawings.

In Figure 15 there is illustrated more or less diagrammatically, one manner in which the individual vanes 11 may be considered as having been formed. In this figure, there is illustrated a substantially cylindrical section 11ª of any metal having the desired thickness for the construction therefrom of individual vanes. This cylinder, having a substantially uniform radius of curvature as to all of its wall parts, is subject to comparatively easy manufacture. In actual practice it may be formed either as a complete cylinder, such as illustrated in Figure 15, or as the arc of a cylinder, as will be apparent.

Having provided the desired parent body of stock curved in the manner referred to, it may be considered as having been intersected by a plane P parallel to and including the axis of the cylinder. This plane P will obviously be substantially normal to a plane tangent to the cylindrical envelope 11ª at the point of intersection between the plane and the envelope. This line of intersection is indicated by the line $p—p$ in Figure 15, which line determines one edge of the entrance vane. This being a straight line, all points in this edge of the vane will provide a constant entrance angle. Thereafter, points p', p^2 and p^3 will be laid off along the surface of the cylinder, which points are sufficient for the determination of a second oblique plane P'. This plane will intersect the surface of the envelope along the line p', p^2 and p^3 and will define the opposite edge of the vane 11. Since all points in the edge defined by the oblique plane P' are at a varying distance from the edge determined by the plane P, the side of the vane 11 determined by the oblique plane will provide discharge angles which constantly vary throughout the length of the vane.

After the desired number of vanes has been formed in this manner, they may be secured in position intermediate rings 12 and 13 in any desired manner, such as by welding the respective ends of the vanes to the respective rings.

From an inspection more particularly of Figures 5 to 9, both inclusive, the relationship of the vanes 11 to the inner and outer rings 12 and 13 will be more clearly apparent, Figures 5 to 9 representing respectively successive sections from the central portion of the apparatus outwardly along the section lines of Figure 4 correspondingly designed. Not only do these figures illustrate the angular relationship of the vanes, but they disclose the relative relationships of the vanes and the impeller at different positions.

Due to the general construction before referred to, the vanes will povide constant entrance angles to the air passing through the vane assembly. These entrance angles E^5, E^6, E^7, E^8 and E^9 are designated in Figures 5 to 9, respectively. Each of these angles is approximately 90°.

While the vane assembly presents entrance angles of constant characteristics, they present discharge angles of varying characteristics, these angles being designated respectively D^5, D^6, D^7, D^8 and D^9 in the figures under consideration. It will be noted that these discharge angles become progressively more and more acute from the inner to the outer ends of the vanes.

By way of illustration only, and in order to afford a better understanding of the invention, without in any wise limiting the same to any specific dimensions, applicant has applied to each of the discharge angles the corresponding value in degrees.

With the apparatus in operation, air is caused to enter the vane assembly in a direction which may be diagrammatically represented by the arrows B in Figures 5 to 9. This air, acted upon by the vanes and under characteristic conditions which will be hereinafter more fully referred to, may be considered as discharged from the vanes in the direction indicated by the arrows C^5, C^6, C^7, C^3 and C^9 in Figures 5 to 9, both inclusive, the direction of these arrows varying with the variation in the corresponding discharge angles of the vanes.

As is also illustrated by the figures under consideration, the vane assembly and the impeller blades are relatively so disposed as to provide an axial space S between the same, the characteristics of which will be hereinafter more fully set forth. In operation, it will be apparent that all portions of the impeller rotate in the same direction, but at speeds increasing in accordance with the distance of any given part from the axis of rotation. If the speed of rotation is known, it is possible to determine the actual velocity of any portion of the impeller structure.

In order to provide an efficient operating construction, it is desirable that the air enter the impeller in a direction substantially parallel to the blades in such manner that the air may be received by the blades without any substantial shock. Such a construction is obtained in accordance with the present invention by utilizing an impeller blade of novel characteristics, determined to a large extent by the characteristics of the vanes 11. This may be best explained by the use of vector diagrams, which for purposes of a better understanding of the invention, have been incorporated in Figures 5 to 9. In all of these figures, the direction of rotation of the impeller being the same, but the velocity of different portions varying in accordance with the radial distance of such portions from the axis of rotation, the lines designated impeller velocity all extend in the same direction but are of different lengths, the lengths being indicative of the diameter at which the section is taken and therefore of the actual velocity. Each of the impeller velocity vectors has applied thereto a numerical value, actually determined for a particular installation and applied by way of illustration only.

Cooperating with the impeller velocity vectors and extending at an angle thereto in the respective figures corresponding to the discharge angles, are air inlet velocity vectors which have heretofore been designated C^5 to C^9, both inclusive. The direction of these vectors is determined by the discharge angle of the corresponding portion of the vane 11, while the length is a matter of experience. With an impeller having radial blades of the properly curved section to eliminate shock at the inlet, the velocity of the entering air becomes substantially uniform over the entire inlet area of the wheel itself. Experience dictates the possibility of utilizing a constant value of the absolute inlet velocity at all radii. This is herein illustrated as being 180 feet per second, this figure being utilized for purposes of illustration only, and represents the velocity intermediate the vanes and the impeller.

From the impeller velocity vector and the air inlet velocity vector, there is obtained a third line, designated, respectively, P^5, P^6, P^7, P^8 and P^9 in the respective figures, and representing the absolute path of entering air relative to the impeller blade. It is the lines P^5 to P^9, both inclusive, which principally determine the contour characteristics of any given portion of an impeller blade. This is true for the reason, as before stated, that it is desirable to have the air enter the impeller in a direction substantially parallel thereto.

By way of concrete illustration, reference will be had to Figure 9, in which the impeller velocity vector has a length corresponding to 340, and in which the air inlet velocity vector has a length corresponding to 180, the included angle between these vectors being 35 degrees, which corresponds to the discharge angle D^9. From these two vectors there is determined the line P^9, hereinbefore designated as the absolute path of the entering air relative to the impeller blade. This line, cooperating with the impeller velocity vector, includes an angle of 29 degrees, as indicated. The contour of the blade section is thus determined, and this section is illustrated in full lines in Figure 9. For more clearly illustrating the relationship, a portion of the blade contour is applied in dotted lines to the vector diagram.

This same procedure is followed in connection with each section of the vane and impeller, and provides a definite basis for a determination of the impeller blade contour. Inasmuch as the respective vector diagrams of Figures 5 to 9 provide absolute paths of entering air, P^5 to P^9, both inclusive, which swing from a position on one side of a perpendicular through the perpendicular into position on the opposite side, the impeller blades have edge portions which correspondingly extend from a position rearwardly of a plane including the axis of rotation to a position forwardly of such plane, as will be apparent from the drawings.

There is thus provided an impeller blade construction every portion of which effectively cooperates with the air as received from the vane and gives to this air the rotational or centrifugal velocity desired for expelling it through the outlet 10 of the snail housing 2.

For stiffening purposes, each of the impeller blades is preferably provided with a back rib 14, extending from the hub of the impeller to the outer end of the blade. For more effectively receiving the air from the vane assembly and holding it within the path of the impeller, the baldes are of curved contour beyond the section lines IX—IX of Figure 4, as apparent more particularly from Figures 10 and 11. This curvature is preferably constant or substantially constant from the plane of the section IX—IX outwardly inasmuch as the primary function of these portions is to impart the desired centrifugal velocity to the air which has previously been received from the vane assembly.

It will be apparent from the foregoing description that the impeller is of the open or unshrouded type, and that the blades extend primarily in a substantially truly radial direction, the cross sectional contour given to the blades varied in different sections in accordance with the absolute paths of the entering air, as before described. It will therefore be apparent that the cross sectional contour given to the blades is for the purpose of bettering the entrance conditions of the air into the impeller.

From the standpoint of rotation of the air as imparted to it by the rotating impeller, the effect, therefore, is substantially the same as if the impeller were composed of plain radial surfaces. Inasmuch as the actual cross sectional contour of the impeller blades at any given point compared to other points, does not depart uniformly or progressively from corresponding sections radially displaced therefrom, it is obvious that the actual contour is not a function of geometry determined from the impeller alone, but is a function of the conditions before referred to as established in large part at least by the vane assembly construction, and therefore constitutes an improved method of determining impeller blade characteristics.

While reference has heretofore not been made to the fact, it will be apparent to those skilled in the art that the vane construction described provides within the inner ring 12, an eye 15, which is unobstructed.

From the standpoint of a blowing apparatus, the present application embodies desirable features; first, in the combination of a stationary vane structure to direct air into an impeller in which there is axial flow into the impeller and radial flow outwardly therefrom. It likewise presents a novel advance in the art with respect to the characteristics of the vane structure, as well as with respect to the characteristics of the impeller, and more especially in the use of an impeller having a blade section such that the air enters the same substantially parallel thereto and without any appreciable shock.

From a manufacturing consideration, advantages arise from the use of a vane structure in which all portions have a given radius of curvature, inasmuch as the production of such a vane is facilitated.

Further advantages arise from the combination of vanes which may be considered as composed of sections of the surface of a cylinder formed between a plane parallel to and including the axis of the cylinder and an oblique plane intersecting the cylindrical surface, the plane of obliquity being so determined that air will be received and delivered to the rotating impeller in a coordinated functional relationship to the blade angles of the impeller.

Reference has heretofore been made to the space S intermediate the vane structure and the runner or impeller. In view of the importance of this space in actual practice, reference will be made to it, and more particularly to its cooperating characteristics to the open eye 15 in the vane structure. At the outset it may be stated that the open hole 15 is desirable from the standpoint of its ability to handle comparatively large volumes of air without the friction losses incident to the use of vanes. It may be considered that there is an annulus of air flow through the vanes 11 of the vane structure upon which the vanes confer a directed, rotative velocity proceeding through the eye of the impeller in the form of a spiral; i. e., rotation and definite progression. All portions of this have been considered as travelling at the same definite velocity, namely, 180 feet per second. In addition to this annulus, there is also an inner core of air through the eye 15 travelling at high velocity.

The velocity is different for the reason that the vanes have not reacted upon it. This being true, the velocity in the space S may be considered as a mixed or resolved velocity determined by the air through the annulus and the air through the hole. It is, of course, a fact that a zone of air travelling into a space under velocity will penetrate further without disintegration if the swirl is lower. In other words, if there were no swirl through the hole 15, the jet or zone of air produced thereby would penetrate further into the space S without losing its identity.

The resolved or mixed velocity in the space S, as before referred to, is progressive radially outward from the shaft. This being true, it is possible both from experience and theory to modify the exit angles D^5 to D^9 on the vane structure to take account of this modification of velocity and to arrive at a resultant direction and modified magnitude of velocity in the vector diagram so that the rotor will pick up the air with less shock. In other words, the cooperation between the hole and stationary vanes produces a result in direction and magnitude of entering velocity so that the rotor shape may be simplified and the entrance angles of the blades become more nearly straight lines, as will be apparent more particularly from Figure 13, in which the vector diagram corresponding to Figure 5 is illustrated in dotted lines and the vector diagram for the construction of Figure 13 illustrated in full lines.

It will be apparent to those skilled in the art that if the vectors P^5 to P^9, both inclusive, could be perpendicular to the vector indicating impeller velocity, there would be no need of curving the blades of the impeller. Obviously, therefore, as the direction and magnitude of the air inlet velocity is modified in direction and magnitude to make the absolute velocity vector perpendicular, benefit is gained. It is to be observed, however, as will be apparent by reference to Figures 5 to 9, both inclusive, that the vector indicating absolute path of entering air without any modifying influence swings through the perpendicular. Therefore, an attempt to modify vector relationship if continued far enough would actually become objectionable and constitute a correction in a wrong direction.

Having this thought in mind, there is incorporated in the space S' of Figure 12, which space obviously corresponds to the space S of Figure 4, a dividing partition 16 in the form of a cylindrical body concentrically disposed with respect to the axis of rotation of the impeller. This partition has for its object to limit the effect of the combination of velocities referred to, to a useful zone whereby an objectionable correction of the character referred to will not be necessary. Such a partition obviously divides the space S' into two more or concentrically disposed spaces such that the modifying influence of one of these spaces on the other is substantially eliminated.

With a construction embodying such a partition, there may be obtained a situation such as illustrated diagrammatically in Figure 13. In this figure, the vector indicating impeller velocity is of the same extent and direction as that shown in Figure 5. The location of the vane 11', however, has been changed so that instead of providing a discharge angle of 53 degrees, as shown in Figure 5, there is provided a discharge angle of substantially 57½ degrees. This, in turn, determines a vector p^5, which more nearly approaches the perpendicular than the vector P^5 by an amount represented by the difference between the dotted vector line for absolute path of entering air and the solid vector line indicating the same value. This makes it possible for the blade 8' of the impeller to have its impact or air receiving edge more nearly approaching a straight line. In this figure, the dotted lines indicate the positions of the parts as indicated in Figure 5 for a structure in which the partition 16 is not utilized, while the full lines indicate the changed position of the parts where advantage is taken of such a partition. This change in the direction of the entering air is made possible by reason of the fact that the influence of the outer envelope of air on the inner zone is restricted by the utilization of a partition of the character described.

Instead of utilizing an impeller as before described, the impeller may be modified as illustrated in Figure 12, by applying thereto a separate nose piece 17 or by extending the impeller in an axial direction so as to provide a modified contour similar to that which is provided by the addition of the nose piece. This modification is made in order to take advantage of the tendency of air having a lesser swirl to travel more nearly intact through a given space. The nose piece or addition to the impeller constitutes in effect a flow directing device in almost identical or similar manner that the stationary vanes are flow directing devices, and its function is to definitely control the outward flow of the central core or zone of air coming through the hole or eye 15. In other words, if the air coming through this hole does not dissipate outward into the wheel and mix with the air coming through the stationary vanes, the function of the nose piece or addition is to direct it outward and perform some mixing after the air has entered the blades of the impeller wheel. Where it is a separate attachment for the impeller, its blade additions are so arranged as to accurately index with the blades on the impeller per se and constitute a continuation thereof.

From a manufacturing standpoint, the use of a separate nose piece is desirable, although from an operating standpoint the characteristics of a separate and integral structure are substantially the same. It will hereinafter be referred to, regardless of whether separable or integral, as a flow directing addition to the impeller.

It will thus be found that the structure of Figure 12 provides the combination with a rotating impeller having a curved blade adapted to receive air without shock in an axial direction, the absence of shock resulting from the cooperation of a stationary structure adapted to receive in a curved vane, an outer annulus of air and to give it a velocity direction modification and having an open central hole, together with the space between the rotor and the stationary vane structure adapted to receive an annulus and core of air, and to so combine them as to secure a favorable resultant velocity relative to the impeller prior to its entering the blades thereof.

The present invention embodies advantages in the respects referred to both from the standpoint of structure involved, and from the method of determining the structural relationship of the parts.

While I have herein illustrated and described certain preferred embodiments of the present invention, it will be understood from such description that changes in the construction and relationship of the parts may be made without departing either from the spirit of the invention or the scope of my broader claims.

I claim:—

1. A blowing apparatus, comprising in combination a casing, an impeller rotatable therein, and a vane structure comprising vanes of uniform curvature but gradually increasing in width outwardly cooperating therewith for directing air into said impeller, said impeller including a plurality of blades having a contour determined by the characteristics of the vane structure for receiving entering air therefrom substantially parallel to the blade faces.

2. The combination in a blowing apparatus, of

a vane structure and impeller, having an axial space therebetween and in which the vane structure includes an open substantially centrally located eye, of means in said space for dividing it into inner and outer zones.

3. A blowing apparatus having an axial inlet and a radial outlet, comprising a casing, an open impeller rotatable therein, and a vane structure cooperating with said impeller for directing air into the impeller, said vane structure comprising vanes providing a discharge angle progressively increasing relative to the impeller axis in a direction radially of the impeller, and the blades of said impeller having air receiving portions of progressively increasing angularity from the center of the impeller toward the periphery thereof throughout the air receiving portion of the impeller.

4. A blowing apparatus having an axial inlet and a radial outlet, comprising a casing, an open impeller rotatable therein, and a vane structure cooperating with said impeller for directing air into the impeller, said vane structure comprising vanes providing a discharge angle progressively increasing relative to the impeller axis in a direction radially of the impeller, and the blades of said impeller having air receiving portions of progressively increasing angularity from the center of the impeller toward the periphery thereof throughout the air receiving portion of the impeller, said vanes being of uniform curvature but gradually increasing width from the inner toward the outer ends thereof.

5. A blowing apparatus having an axial inlet and a radial outlet, comprising a casing, an open impeller rotatable therein, and a vane structure cooperating with said impeller for directing air into the impeller, said vane structure comprising vanes providing a discharge angle progressively increasing relative to the impeller axis in a direction radially of the impeller, and the blades of said impeller having air receiving portions of progressively increasing angularity from the center of the impeller toward the periphery thereof throughout the air receiving portion of the impeller, said vanes having outer substantially straight air receiving edges and outwardly diverging air discharge edges and having a substantially uniform radius of curvature from one end to the other.

6. A blowing apparatus having an axial inlet and a radial outlet, comprising a casing, an open impeller rotatable therein, and a vane structure cooperating with said impeller for directing air into the impeller, said vane structure comprising vanes providing a discharge angle progressively increasing relative to the impeller axis in a direction radially of the impeller, and the blades of said impeller having air receiving portions of progressively increasing angularity from the center of the impeller toward the periphery thereof throughout the air receiving portion of the impeller, said vanes being shaped to provide a substantially constant angle for the entering air throughout the length of the vanes with a discharge angle of progressively increasing acuteness from the inner toward the outer ends of the blades.

7. A blowing apparatus having an axial inlet and a radial outlet, comprising, in combination, an impeller having blades of changing cross section throughout a portion of the length thereof, and a guide vane structure for directing air into said impeller, said guide vane structure including vanes providing a varying air discharge angle from the inner to the outer ends thereof, the variation in the cross section of said blades being proportionate to the variation in the air discharge angle of said vanes.

8. Blowing apparatus, having an axial inlet and a radial outlet, comprising, in combination, an impeller having a plurality of blades of gradually increasing curvature in cross section from their inner portions to their outer portions throughout a substantial part of their length, and a vane structure including a plurality of vanes for directing air to said impeller, said vanes being of substantially uniformly curved cross section throughout substantially the entire length thereof and so disposed as to provide discharge angles varying throughout the length of each vane in accordance with the varying cross section of the impeller blades.

9. Blowing apparatus, having an axial inlet and a radial outlet, comprising, in combination, an open impeller having a plurality of blades providing curved air receiving portions, and a vane structure including a plurality of vanes, said vanes and blades being of such contour as to direct the entering air from the vanes into the impeller substantially parallel to the curved air receiving portions of the impeller blades.

10. Blowing apparatus, having an axial inlet and a radial outlet, comprising, in combination, an open impeller having a plurality of blades providing curved air receiving portions, and a vane structure including a plurality of vanes, said vanes and blades being of such contour as to direct the entering air from the vanes into the impeller substantially parallel to the curved air receiving portions of the impeller blades, said vanes being substantially radially disposed and of increasing width from their inner toward their outer ends.

11. Blowing apparatus, having an axial inlet and a radial outlet, comprising, in combination, an open impeller having a plurality of blades providing curved air receiving portions, and a vane structure including a plurality of vanes, said vanes and blades being of such contour as to direct the entering air from the vanes into the impeller substantially parallel to the curved air receiving portions of the impeller blades, said vanes being substantially radially disposed and of increasing width from their inner toward their outer ends, and having a substantially uniform curvature throughout their length.

12. In a blowing apparatus having an axial inlet and a radial outlet, a vane structure, and an open impeller, said vane structure including a plurality of vanes effective for directing air into the impeller, and having a continuously curved cross sectional contour providing entrance angles for the entering air substantially constant from the outer periphery of the vane structure toward the center thereof, and discharge angles for the air of gradually increasing acuteness from the center of the vane structure toward the periphery thereof, said impeller including a plurality of blades having curved air receiving portions.

13. Blowing apparatus having an axial inlet and a radial outlet, comprising a casing, an open impeller including a plurality of blades rotatable in said casing, and means cooperating with said impeller for directing air into said impeller substantially parallel to the front faces of said blades, said blades having front faces of varying curved cross sectional contour throughout at least a portion of their length.

14. In a blowing apparatus having an axial

inlet and a radial outlet, the combination with an impeller having blades providing variously curved portions in a direction transversely thereof at different distances along their lengths, of flow directing means cooperating therewith and including vanes providing a substantially constant entrance angle with a discharge angle becoming more and more acute toward the outer ends thereof.

15. In a blowing apparatus having an axial inlet and a radial outlet, the combination with an open impeller having blades providing portions curved in a direction transversely thereof with the curvature increasing in a direction outwardly from the center of the impeller, of flow directing means cooperating therewith and including vanes substantially uniformly curved transversely thereof throughout their length, said blades having a width increasing from their inner toward their outer ends providing air discharge angles of increasing acuteness from the center of the flow directing means toward the periphery thereof for directing air into the impeller substantially parallel to the curved faces of the impeller blades.

PAUL E. GOOD.

CERTIFICATE OF CORRECTION.

Patent No. 1,931,692. October 24, 1933.

PAUL E. GOOD.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, line 60, for "given to the blades" read , however, having; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 5th day of December, A. D. 1933.

F. M. Hopkins
Acting Commissioner of Patents.

(Seal)

CERTIFICATE OF CORRECTION.

Patent No. 1,931,692. October 24, 1933.

PAUL E. GOOD.

It is hereby certified that the Certificate of Correction issued December 5, 1933, was erroneously drawn as to the word "having" and that this Certificate should have read as follows: page 3, line 60, for "given to the blades" read ,however, being; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 23rd day of January, A. D. 1934.

F. M. Hopkins
Acting Commissioner of Patents.

(Seal)