

Oct. 23, 1956

D. I. DOYLE

2,767,906

CENTRIFUGAL FAN WHEEL

Filed Nov. 7, 1952

2 Sheets-Sheet 1

FIG. 1

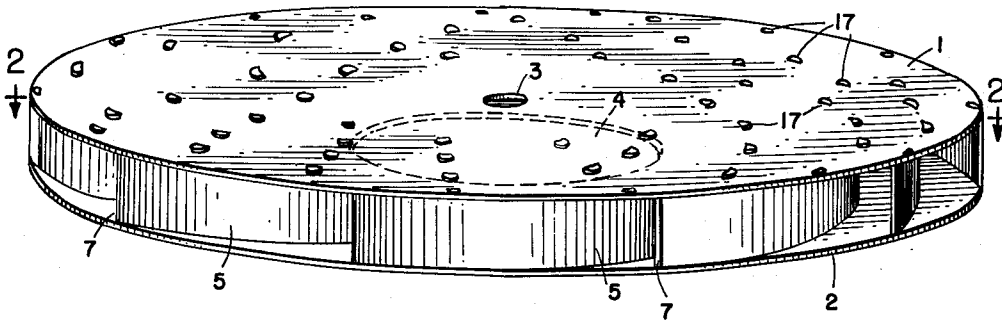
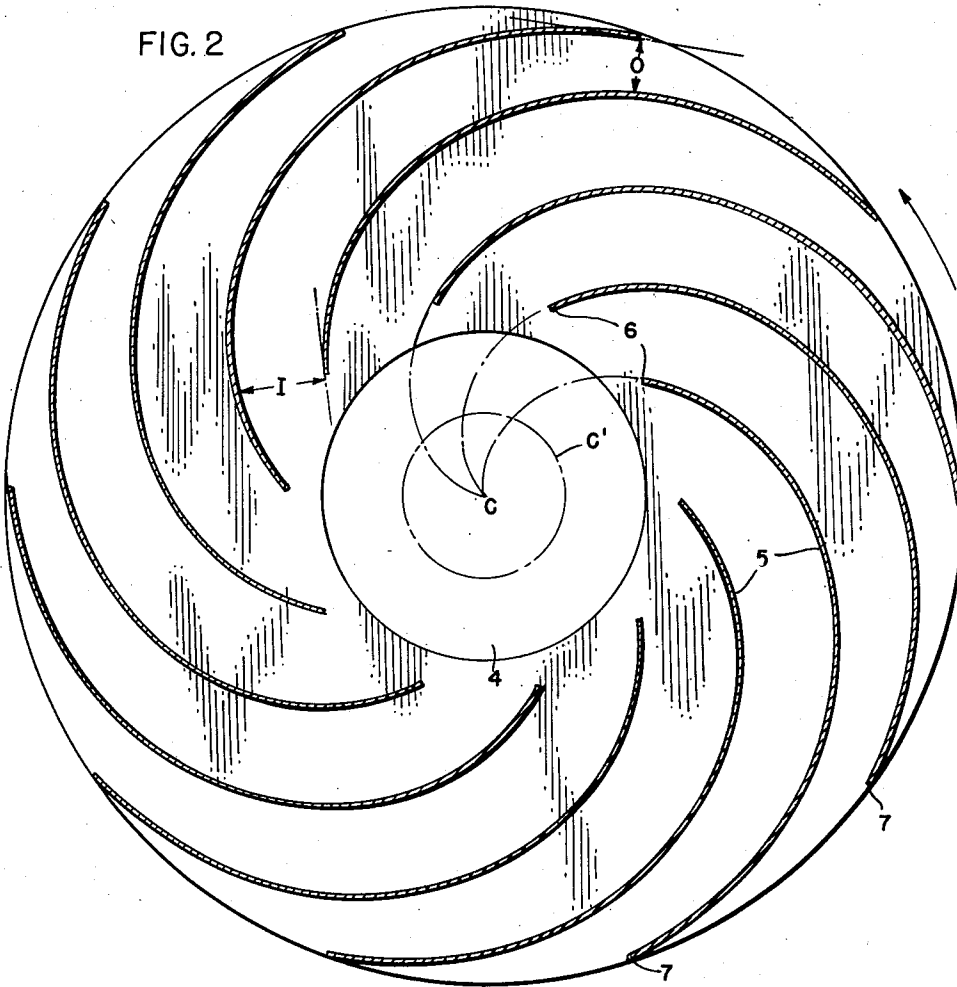


FIG. 2



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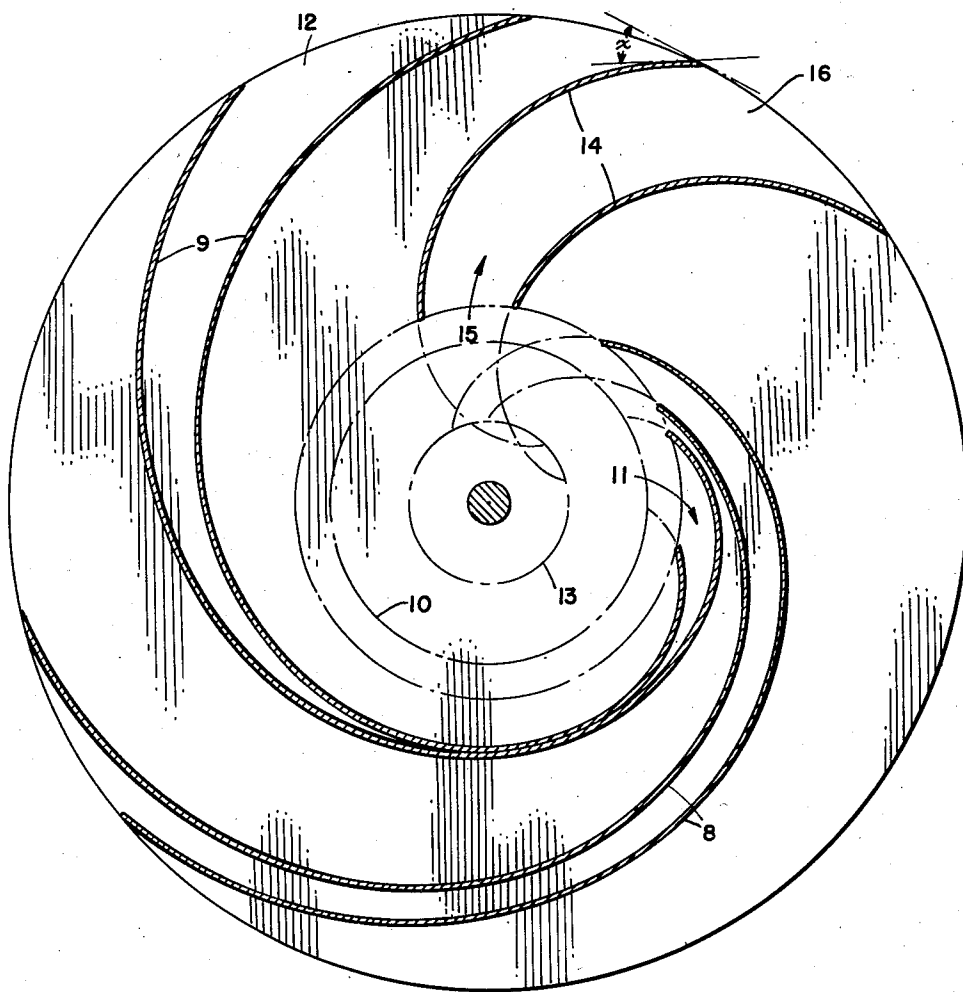
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FIG. 3



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CENTRIFUGAL FAN WHEEL

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Application November 7, 1952, Serial No. 319,375

8 Claims. (Cl. 230—134)

This invention relates in general to centrifugal fan wheels and is more particularly directed to improvements in such fan wheels which are especially designed to create either a suction or a blowing effect.

The improved centrifugal fan wheel embodying the present invention may have many uses in combination with various types of machines to produce various results. However, the particular design disclosed herein is especially adapted for use in vacuum cleaners.

It has been customary in the past to design vacuum cleaners either for the production of high volume or for the production of what is known as a high static suction. In commercial or industrial tank type vacuum cleaners the particular design has in the past depended upon the end use of the vacuum cleaner. Where the purchaser of the product expects to use the vacuum cleaner with the hose substantially open he is more interested in a high volume of air passing through the machine.

However, where the machine is to be used under circumstances where the hose end will be partially closed such as in the cleaning of rugs and upholstered furniture, it is more desirable that a high static condition prevail.

Up to the present time vacuum cleaners which are designed to produce a high volume inherently have a low static condition; likewise, a machine that is especially designed to produce a high static will inherently result in a reduced volume.

In order to more clearly understand the terms "high" or "low static" and "high" or "low volume," a brief description of the test involved in determining these factors will be presented. The actual amount of static or volume is customarily stated in terms of water lift. In running tests to determine these factors, a U-shaped tube is employed having a predetermined number of inches of water therein. One end of the U tube remains open to the atmosphere and the other end of the U tube is connected by means of a hose to an opening in the side of the inlet into the vacuum cleaner tank. With the machine in operation and creating a vacuum at the inlet to the tank the water lift will be increased as the size of the inlet is decreased. When the inlet is completely closed the number of inches that the water is drawn upwardly into one side of the U tube and is forced downwardly in the other side of the U tube is referred to as the "closed water lift." This is a measure of the static suction.

As the inlet opening to the tank is enlarged in area the water in the U tube will fall and the number of inches of water lift for a given size opening may then be translated into terms of volume.

Industrial tank type vacuum cleaners designed particularly to produce a high volume or a relatively high water lift when the inlet to the tank is completely open usually have a single fan wheel commonly known as a single stage. Fan wheels which have been designed up to the present time when used as a single stage are incapable of producing a very high static suction and can therefore be used only for specific purposes.

In order to increase the static suction in a vacuum cleaner it is customary to increase the number of fan wheels to two or three and sometimes more all mounted on the same motor shaft. These are commonly termed "multistage units" the number of stages depending upon the number of fan wheels used. When this is done it becomes necessary that the air pass through the center and out of the periphery of the first fan wheel and then be directed back into the center of the second wheel and so on until the periphery of the last wheel is reached. The result of this construction is to increase the static suction or closed water lift but, at the same time, the volume of air passing through the machine will be materially reduced.

The present invention is directed to a novel form of centrifugal fan wheel which is capable of producing in a single stage machine a relatively high static suction as well as a relatively high volume whereby the same machine may have its end uses multiplied considerably, i. e., a machine embodying the present invention will be usable for any purpose whether a high volume or a high static is desired.

In view of the foregoing it is therefore one of the principal objects of the present invention to provide a centrifugal fan wheel which is capable of producing a relatively high static suction and a relatively high volume in a single stage vacuum cleaner.

Another object of the invention is to provide a centrifugal fan wheel for use in either vacuum producing machines or blowers which will produce a higher static condition in a single stage machine than in a multistage machine of the same size presently in use and which will also produce a higher volume than the volume type machines presently in use.

A further object of the invention is to provide a centrifugal fan wheel which includes a pair of axially spaced disks wherein a plurality of blades having an involute form are disposed between those disks.

A still further object of the invention is to provide a centrifugal fan wheel wherein two disks are spaced apart in an axial direction with a plurality of blades located between the disks and wherein each blade is in the form of an involute and arranged around the wheel with the center of the generating circle for the involute being offset from the center of the wheel.

Still another object of the invention is to provide a centrifugal fan wheel for a compressible fluid wherein a plurality of involute blades are disposed between two flat disks. These blades are so arranged around the wheel that the inlet area between adjacent blades at the inner or heel ends thereof is greater than the outlet area between adjacent blades at the outer or tip ends thereof whereby the fluid passing through the space between adjacent blades will be compressed.

Still further and specific object of the invention is to provide a centrifugal fan wheel adapted for use with compressible fluids wherein a plurality of blades of involute form are equally spaced around the wheel between two flat disks and wherein the center of the generating circle for each involute blade is offset from the center of the wheel approximately the radius of the generating circle.

It is also a specific object of the invention to form the involute blades using a generating circle having a diameter approximately one-sixth the diameter of the fan wheel formed by the disks between which the blades are located whereby to achieve proper length of air passage and proper heel and tip angles to result in maximum static and volume conditions in a vacuum producing machine.

Other objects and advantages of the invention will become apparent upon reading the following description

taken in conjunction with the accompanying drawings in which:

Fig. 1 is a perspective view of a fan wheel embodying the present invention;

Fig. 2 is a horizontal sectional view through the fan wheel taken along the plane of line 2—2 of Fig. 1; and

Fig. 3 is a somewhat diagrammatic illustration of pairs of involute blades which have been generated from a generating circle of the same size as that of Fig. 2, but with the center of the generating circle at different locations with respect to the center of the wheel.

The centrifugal fan wheel embodying the present invention has certain desirable characteristics all of which contribute in a measure to the improved result of being able to achieve a higher static suction and a higher volume with a single wheel than has heretofore been accomplished by the use of either single or multistage wheels. In designing the fan wheel disclosed herein there is illustrated the preferred characteristics although it will be understood that some of these characteristics may be altered within limits without seriously affecting the result.

For example, it was first determined by various tests that an involute was the best form of blade which could be used to achieve the desired results. When it is considered that the involute of a circle is a curve generated by the end of a string which is kept taut while being unwound from a circle, it will be understood that for a given diameter fan wheel it would be possible to utilize circles of various diameters. It is also possible to locate the center of the generating circle or evolute in different positions with respect to the center of the wheel and thereby obtain different results.

Consideration must also be given to the length of passage between the blades or to the length of the blades themselves because if the blades are too long the resulting increased resistance to the passage of air therethrough will adversely affect the results desired.

Furthermore, the angle of a tangent at the tip end of the blade with a tangent to the wheel at the point where the tip end of the blade terminates has a very definite effect upon the results. For example, the greater the angle the more feedback will occur resulting in less volume and less static delivery. It follows that a smaller angle at the tip is desirable although the smaller the angle the greater will be the length of the blade resulting again in increased resistance to air flow.

Consideration must also be given to the fact that the air which enters at the center of the fan wheel is relatively rarefied and it is therefore desirable that this air be compressed to a degree at the point of its outlet from the fan wheel. To achieve this result it was found desirable to have the inlet area between adjacent blades at the center of the wheel be greater than the outlet area between adjacent blades at the periphery of the wheel.

The use of a true center involute where the center of the generating circle or evolute is common to the center of the wheel produces a plurality of blades which are parallel throughout their length resulting in inlet and outlet areas between adjacent blades which are identical; therefore, no compression of the fluid can take place. Also, when this is done it has been found that the length of the blades create undesirable resistance thereby adversely affecting the result by decreasing the volume.

In order to arrive at a blade design of an involute form where the blade was not too long, where the angle of a tangent at the tip end of the blade with the tangent on the periphery of the wheel at a point coincident with the blade tip would be small enough to reduce feedback of the air, and where the inlet areas between adjacent blades would be greater than the outlet area thereof, it was necessary to conduct many experiments using generating circles of varying diameters and locating the centers of the generating circles at various distances from the center of the wheel. It was found that for a fan wheel having a seven and one-half inch diameter the best results were

obtained by using blades of involute form where the involute was generated from a circle or evolute having a diameter of one and one-fourth inches. It was also found that for a fan wheel of six inch diameter, best results were obtained by using a generating circle of one inch diameter to generate the involute form of the blades. With this in mind the diameter of the generating circle should be about one-sixth of the diameter of the fan wheel to be used in order to achieve both the highest volume and highest static delivery.

In arranging the involute blades which were generated from the predetermined diameter of generating circle ground the wheel in such a manner to obtain minimum feedback, minimum resistance and desired compression of the fluid, it became necessary to locate the center of the generating circle for each blade in offset relation with the center of the wheel. Various distances for the wheel center and various directions therefrom were attempted with the result that the arrangement of the blade shown in Fig. 2 was determined to give maximum results.

Having the foregoing in mind, reference will now be made particularly to the drawings and especially to Fig. 1 wherein it will be seen that the fan wheel is composed of the two axially spaced apart disks 1 and 2. The upper disk 1 is commonly called the back of the wheel whereas the lower disk 2 is referred to as the shroud. The back 1 is provided with a central opening 3 for the reception of a shaft and the shroud 2 has the central opening 4 therein to receive the compressible fluid such as air and direct it to the passages between the blades 5 as the wheel rotates in a counterclockwise direction as viewed in Fig. 2.

Each blade 5 is formed preferably of sheet metal and takes the form of an involute curve. Fig. 2 represents the preferred embodiment of the invention and illustrates the location of the involute blades to achieve best results. It will be understood that variation in the specific location of each involute blade 5 may be made without effecting substantially the end results but the greater the variation the greater the result will be affected. This will be brought out more clearly hereinafter when specific reference is made to Fig. 3 which illustrates other locations of involute blades which are unsatisfactory.

The inner end 6 of each blade 5 is called the heel of the blade whereas the outer end 7 is called the tip thereof. Having in mind that the results with respect to both volume and static suction will vary depending upon the length of each blade, the inlet area between adjacent blades near the center of the wheel, the outlet area between adjacent blades at their tip ends, and the angle formed between the tangent to the involute curve at the tip of each blade with the tangent to the circle formed by the tips of the blades at the point where the tip of the blade meets such circle, all of these factors have been considered in arriving at the particular layout of the blades shown in Fig. 2.

Experiments were conducted using disks 1 and 2 having a diameter of seven and one-half inches. Involute curves having various diameters of generating circles were tried and it was determined that the best results were obtained with an involute curve having a generating circle of one and one-fourth inches in diameter. Other experiments with other disks of different diameters indicated best results to be obtained by the use of involute curves having different diameters of generating circles. For example, when the disks 1 and 2 were six inches in diameter it was found that best results were obtained by the use of an involute curve having a generating circle of one inch diameter. In this way it was established that the preferred form of the invention should utilize an involute curve where the diameter of the generating circle is substantially one-sixth the diameter of the wheel in which the blades are to be used.

It will be noted in Fig. 2 that the blades 5 are laid out in an involute form where the involute is generated

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in a clockwise direction. Viewing the same wheel from the opposite side, the involute blades would be generated in a counterclockwise direction. This fact must be borne in mind when defining the location of the center of the generating circle for the involute with respect to the center of the same wheel.

When the center of the generating circle is coincident with the center of the wheel and the involute blades are formed in spaced apart relation, it will be evident that all of the blades will be parallel throughout their entire length in accordance with the blades 8 in Fig. 3. This arrangement does not satisfy two of the requirements mentioned above, namely, that the inlet area between adjacent blades be greater than the outlet area. Where the blades are parallel as indicated by the numeral 8 the inlet and outlet areas will be substantially identical so that no compression of the fluid will take place. It will also be noted that the length of blades 8 is considerably greater than the length of the blades 5 thereby resulting in increased resistance to the passage of the fluid therebetween.

It was thus discovered that the center of the generating circle for the involute should be offset from the center of the fan wheel and experimentation was then necessary to determine the amount of the offset and the direction thereof from the center of the wheel. When speaking of the center of the generating circle being offset from the center of the fan wheel as used herein, it is understood to mean that the initial position of the generating circle is that at which the starting point of the involute is at the left of the center of the generating circle and in a position to generate the involute in a clockwise direction.

Fig. 3 illustrates the results of three positions of the generating circle all of which produce unsatisfactory results. The positioning of the generating circle so that the center thereof is coincident with the center of the fan wheel has already been mentioned above and was described as resulting in the parallel blades 8. When, however, the center of the generating circle is moved toward the left of the center of the fan wheel a distance equal to the radius of the generating circle so that the starting points of all of the involute blades will be on a circle having a radius twice that of the generating circle, the result will be to produce blades like those indicated by the numeral 9. It will, of course, be understood that for each blade the generating circle is moved from its initial starting position so that a line passing through the starting point of the involute curve and the center of the generating circle will also pass through the center of the wheel. Thus the dot-dash circle indicated by the numeral 10 is that on which each involute begins.

When adjacent blades are separated a distance of 36 degrees so that there will be a total of ten blades for the wheel, it will be noted that the blades 9 practically touch at one point along their length so that air passing from the inlet 11 between adjacent blades to the outlet 12 will go through a compression stage and then an expansion stage and the resistance thus offered for this reason and for the additional reason that the blades are unduly long will produce very unsatisfactory results. The volume will definitely be decreased due to the increased resistance and thus the objective of maintaining both high volume and high static conditions will not prevail.

When the position of the generating circle is initially as mentioned above and then moved toward the right of the center of the fan wheel a distance equal to twice the radius of the generating circle so that the starting points of all involute blades will be on the circle identified by the numeral 13 the resulting blades will have the configuration of the blades indicated by the numeral 14. Again the blades 14 are spaced apart an angle of 36 degrees around a circle on any given radius from the center of the wheel to provide a total of ten blades only two of which are shown in Fig. 3.

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This construction and arrangement of blades is also unsatisfactory for several reasons. It will first be noted that the inlet area 15 between the two blades 14 is less than the outlet area 16 whereby the fluid will not be compressed. In addition to the foregoing the angle x between the tangent to the involute curve at the tip of the blade and the tangent to the periphery of the wheel at the point where the blade tip meets the periphery is relatively large thereby producing leak-back of the fluid and again producing less volume.

Further experimentation indicated that positioning the generating circle of the involute toward the right of the center of the wheel when the generating circle is positioned so that the starting point of the involute is at the left of the center of the generating circle and in a position to generate the involute in a clockwise direction produced improved results. The best results were found to obtain when the generating circle was moved toward the right a distance equal to the radius of that circle and that is the position of the blades 5 illustrated in Fig. 2. In this construction the center of the generating circle is located at a point on the circle C' so that the starting point of the involute for all blades is at the center C of the fan wheel. All of the desired conditions are met in this construction. For example, it will be noted that the length of blades 5 is less than the length of blades 8 or 9 in Fig. 2 thereby satisfying one requirement that the blades be of a length to create the minimum resistance for fluid flow when the other factors are also considered.

Also, since the axial distance between the two disks 1 and 2 is constant throughout their area the distance between blades at their inlet and outlet ends will govern the inlet and outlet areas. The inlet area between adjacent blades 5 may be governed by the distance I measured on a perpendicular line from the tangent at the heel of one blade to the next adjacent blade. Likewise, the outlet area between adjacent blades is governed by the distance O between blades measured on a perpendicular line from the tangent at the tip of one blade to its adjacent blade. Thus it will be seen that the distance I is greater than the distance O so that the outlet area is less than the inlet area and a compression of the fluid will result.

This arrangement also provides for a small enough angle between the tangent at the tip of each blade and the tangent to the wheel at the same point so as to reduce leak-back and thus increase volume.

Obviously, the center of the generating circle may be initially moved toward the right of the center of the wheel under the conditions above stated, varying distances to obtain varying results. It has been established, however, as is evident from viewing the blades 14 in Fig. 3 that moving the center of the generating circle toward the right a distance twice the radius of the generating circle will give unsatisfactory results so that it follows that the distance toward the right which this center should be moved must be a distance less than twice the radius of the generating circle.

It has also been established that when the centers of the generating circle and of the wheel are coincident the result is also unsatisfactory as is evident from viewing the blades 8 on Fig. 3 since the blades are parallel throughout their entire length and are relatively long. It therefore follows that for best results the center of the generating circle should be moved toward the right of the center of the wheel a distance less than twice the radius of the generating circle and preferably a distance equally substantial to the radius of the generating circle as illustrated in Fig. 2.

Although the fan wheel embodying the present invention may be fabricated in various ways, the preferred manner is to form each involute blade of sheet metal with a plurality of ears along each edge of the blade in spaced apart relation. Each of the disks 1 and 2 embodying the back and the shroud of the fan wheel is also provided with a series of slotted openings, adapted to receive the ears on

each of the blades. Each series of openings in a disk for each blade will be located along the line of an involute of the same size as the involute used to produce the blades. The various parts are then assembled so that the ears 17 on each blade may extend through the corresponding slots on each disk. The ears 17 are then bent over against each adjacent disk whereby all of the blades are held in place in their proper relation positions.

Reference has heretofore been made to the static suction or closed water lift obtainable by the use of a fan wheel embodying the present invention as illustrated in Figs. 1 and 2. In actual practice it has been found that a fan wheel having a seven and one-half inch diameter with ten involute blades spaced equally around the wheel having a generating circle of one and one-fourth inch diameter and offset according to the arrangement of Fig. 2 will produce a closed water lift of approximately sixty-seven inches. It has not been possible heretofore to achieve that amount of closed water lift with a single stage fan having a diameter on the order of seven and one-half inches. The volume obtainable in the present fan wheel is not reduced below that which would be obtained by any other single stage vacuum producing machine. Such other machines, however, in order to acquire a closed water lift of sixty-seven inches would have to be provided with a plurality of fan wheels thus causing a considerable reduction in the volume obtainable. The present invention therefore results in unusually high static suction and volume in the same machine with the use of but a single fan wheel.

It will be evident also that the number of blades used might vary with varying results although it has been found that anywhere from eight to twelve blades will produce satisfactory results, the number of blades being shown herein for purposes of illustration being ten.

Changes may be made in the form, construction and arrangement of parts from those disclosed herein without in any way departing from the spirit of the invention or sacrificing any of the attendant advantages thereof, provided, however, that such changes fall within the scope of the claims appended hereto.

The invention is hereby claimed as follows:

1. A centrifugal fan wheel comprising at least one disk, and a plurality of blades of involute form disposed on said disk and secured thereto, the center of the generating circle for each involute blade being offset from the center of rotation of the wheel.

2. A centrifugal fan wheel comprising two disks in axially spaced relation, and a plurality of blades of involute form disposed between said disks and secured thereto and arranged to be equal distances apart on any given radius from the center of the wheel, the center of the generating circle for each involute blade being offset substantially the same distance from the center of rotation of the wheel.

3. A centrifugal fan wheel comprising two disks in axially spaced relation, and a plurality of blades of involute form disposed between said disks and secured thereto, the center of the generating circle for each involute blade being offset from the center of rotation of the wheel a distance less than the diameter of said generating circle.

4. A centrifugal fan wheel comprising two disks in axially spaced relation, and a plurality of blades of involute form disposed between said disks and secured thereto, the center of the generating circle for each in-

volute blade being offset from the center of rotation of the wheel a distance substantially equal to the radius of said generating circle.

5. A centrifugal fan wheel comprising two disks in axially spaced relation, and a plurality of blades of involute form disposed between said disks and secured thereto, the center of the generating circle for each involute blade being offset toward the right from the center of rotation of the wheel when the starting point of the involute curve is at the left side of the generating circle and the curve is generated in a clockwise direction, the amount of said offset being substantially equal to the radius of the generating circle.

6. A centrifugal fan wheel for compressible fluids comprising two disks in axially spaced relation, one of said disks having an inlet opening at the center thereof for the passage of fluid, and a plurality of blades of involute form equally spaced around the wheel and between said disks, the center of the generating circle for each involute blade being offset from the center of rotation of the wheel, and arranged so that the fluid inlet area between adjacent blades at the heels thereof is greater than the fluid outlet area between adjacent blades at the tips thereof, whereby the fluid will be compressed during the passage thereof between the blades.

7. A centrifugal fan wheel for compressible fluids comprising two flat disks in axially spaced relation, one of said disks having an inlet opening at the center thereof for the passage of fluid, and a plurality of blades of involute form disposed between said disks and secured thereto and arranged to be equal distances apart on any given radius from the center of the wheel, the center of the generating circle for each involute blade being offset from the center of rotation of the wheel, and the distance on a perpendicular line from the tangent at the heel of any one blade to the next adjacent blade being greater than the distance on a perpendicular line from the tangent at the tip of said adjacent blade to the first blade, whereby the fluid will be compressed during the passage thereof between the blades.

8. A centrifugal fan wheel for compressible fluids comprising two flat disks in axially spaced relation, one of said disks having a fluid inlet opening at the center thereof, and a plurality of blades of involute form disposed between said disks and secured thereto and arranged to be equal distances apart on any given radius from the center of the wheel, the center of the generating circle for each involute blade being offset from the center of rotation of the wheel, and the area of the inlet opening between adjacent blades being greater than the outlet opening between said blades, whereby fluid will be compressed during the passage thereof between the blades.

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