United States Patent [19]
Troller

[11] 3,867,062
[45] Feb. 18, 1975

[54] HIGH ENERGY AXIAL FLOW TRANSFER STAGE

[76] Inventor: **Theodor H. Troller**, Ava Banch, Portal, Ariz. 85632

[22] Filed: **Sept. 19, 1973**

[21] Appl. No.: **398,654**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 183,413, Sept. 24, 1971, abandoned.

[52] **U.S. Cl.** **415/194,** 415/DIG. 1, 416/236
[51] **Int. Cl.** **F04d 29/32**
[58] **Field of Search** 415/DIG. 1, 213, 194; 416/236, 183

[56] **References Cited**

UNITED STATES PATENTS

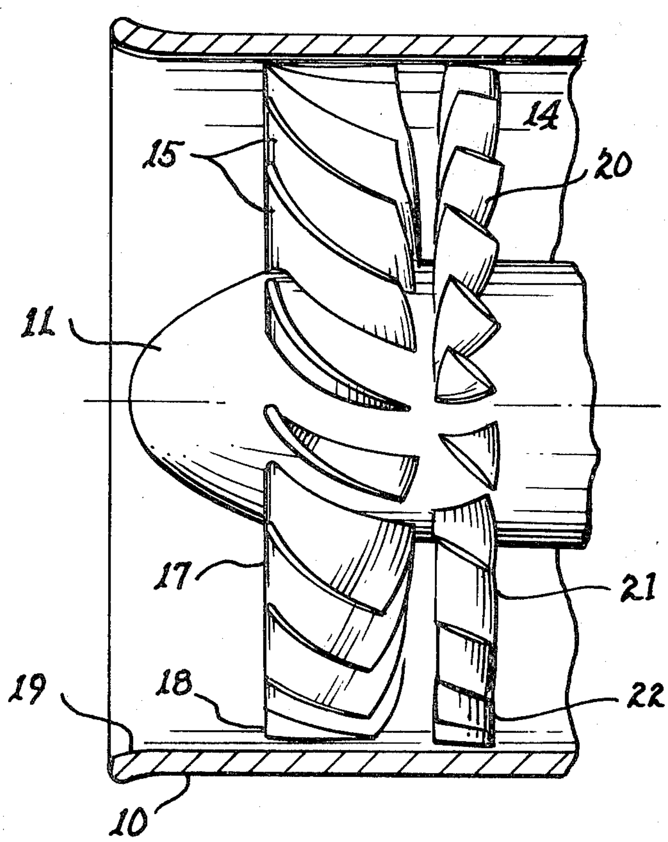
1,744,709	1/1930	Moody	415/DIG. 1
1,836,860	12/1931	Moody	415/130
2,314,572	3/1943	Chitz	415/DIG. 1
2,576,700	11/1951	Schneider	415/DIG. 1
2,920,864	1/1960	Lee	415/DIG. 1
2,935,246	5/1960	Roy	415/DIG. 1
2,938,662	5/1960	Eckert et al.	415/DIG. 1
2,982,361	5/1961	Rosen	415/129
3,075,743	1/1963	Sheets	415/DIG. 1
3,112,866	12/1963	Fortescue	415/DIG. 1
3,128,939	4/1964	Szydlowski	415/181
3,692,425	9/1972	Erwin	416/236
3,768,546	10/1973	Shipes	415/130

Primary Examiner—Henry F. Raduazo
Attorney, Agent, or Firm—Cahill, Sutton & Thomas

[57] ABSTRACT

Axial flow apparatus for transferring substantial energy to a fluid utilizing a stage having two sets of pluralities of blades secured to and extending radially from a rotor. The first set of energy adding blades, called the main blades, incorporates an airfoil section that is warped or twisted from its root at the rotor to its tip adjacent the housing. The airfoil shape and other design characteristics of the main blades may be conventional and of the type commonly found in axial flow pumps, blowers, and compressors. A second plurality of energy adding blades, which may be referred to as auxiliary blades, is provided and is positioned downstream from the main blades without intervening stationary vanes and may be located either directly behind corresponding main blades or may be circumferentially displaced forward or backward in the direction of blade travel. The leading edges of the auxiliary blades are angled with respect to, or are not parallel, to the trailing edges of the main blades. The blades are warped or twisted from a root cross section that exhibits a chord forming an angle of greater than 90° with the plane of rotation of the blades. The trailing edge of the auxiliary blades at the respective blade roots is thus placed away from the main blades and points into the direction of rotation.

3 Claims, 6 Drawing Figures



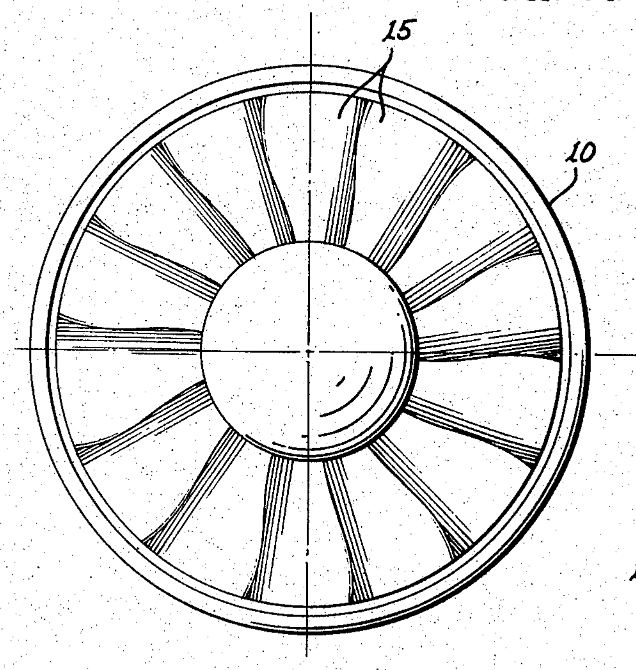


fig. 1

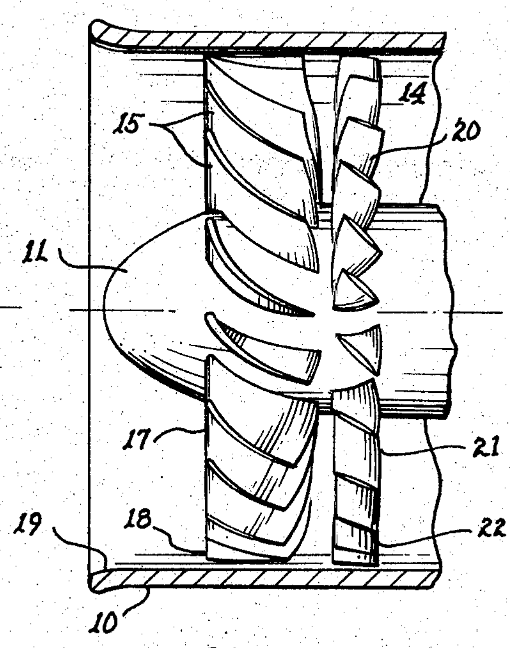


fig. 2

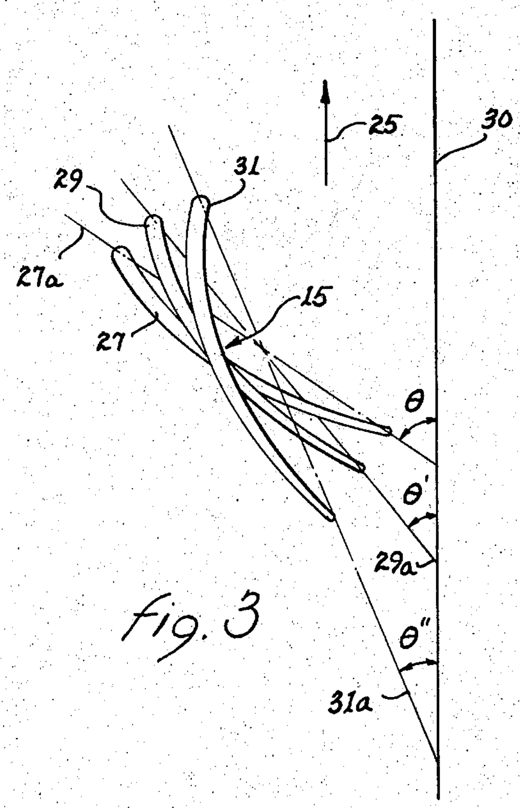


fig. 3

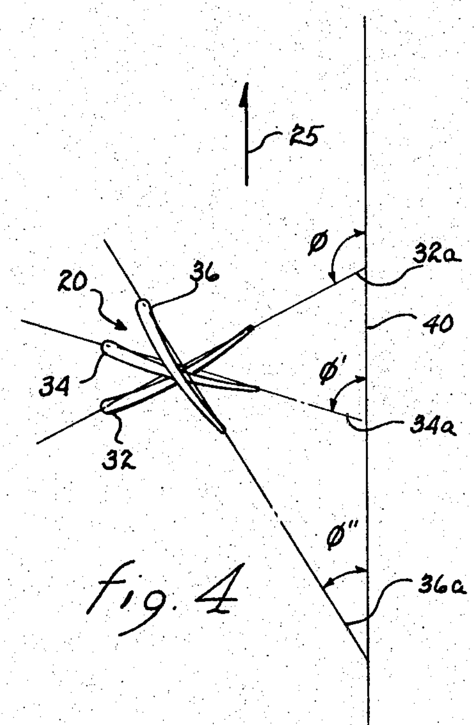


fig. 4

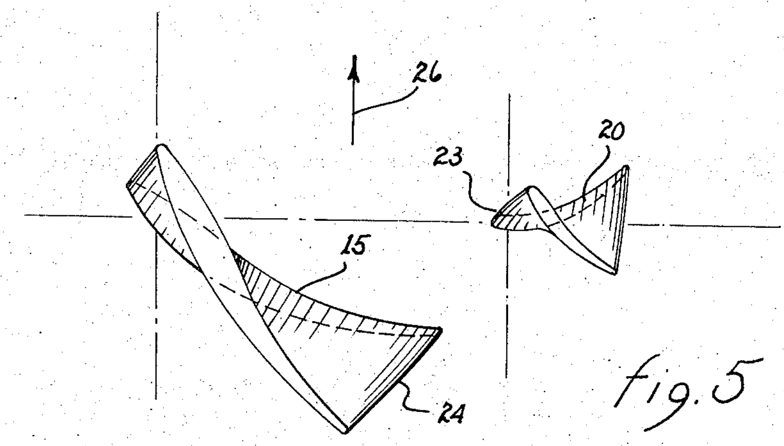


fig. 5

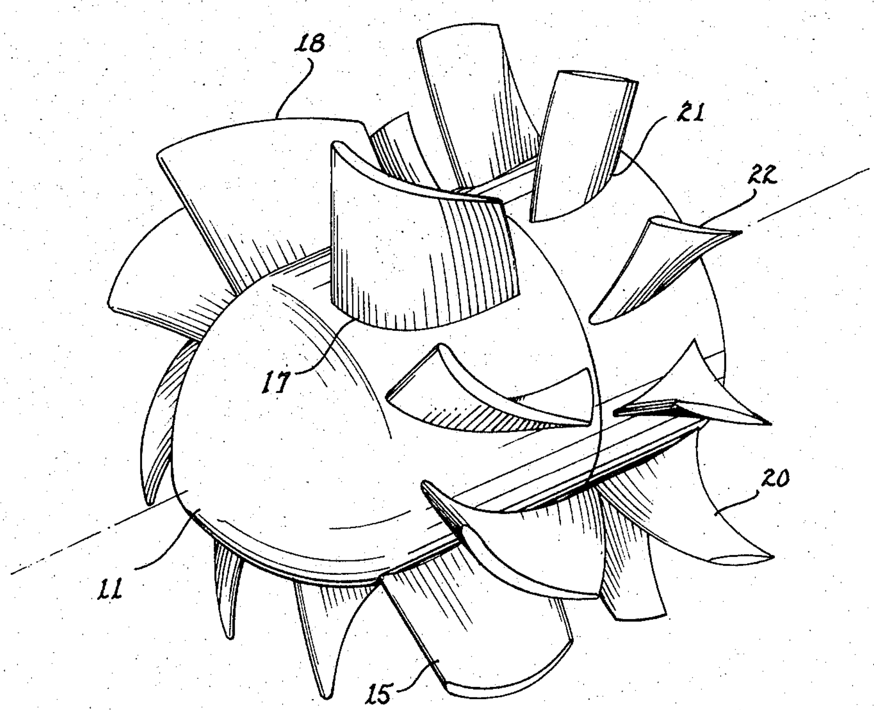


fig. 6

HIGH ENERGY AXIAL FLOW TRANSFER STAGE

This application is a continuation-in-part of my copending application Ser. No. 183,413, filed Sept. 24, 1971, entitled "High Energy Axial Flow Transfer Stage" now abandoned.

The present invention pertains to axial flow apparatus, and more particularly, to apparatus for imparting high energy to a fluid.

In axial flow compressors, pumps, and blowers, energy is imparted to the fluid through the relative motion of the fluid and the blades mounted on and rotating with a rotor. Energy transfer can be controlled therefor by both blade design as well as blade velocity. To impart substantial energy to a fluid, different blade designs have been utilized and blade classifications, such as reaction blades or impulse blades, have resulted. The advantages and limitations of these two types of blade designs are discussed in my U.S. Pat. No. 3,291,381, wherein I teach the design of a compact impeller-blade giving impulse-type energy transfer at the hub and reaction-type energy transfer in the outer parts of the blades.

The impeller design described by me in the above patent permits the apparatus to impart a greater energy to the fluid than previously possible; however, the utilization of an impeller or blade having an impulse configuration of crescent shape at the hub and a reaction configuration at the tip, while effective, presents other problems. Specifically, the crescent shape near the hub, and the transition thereof to the outer sections, brings about air pockets which result in undesirable flow patterns under certain operating conditions; further, the manufacturing technique may be quite involved.

It is therefore an object of the present invention to provide an axial flow stage for imparting high energy to a fluid.

It is another object of the present invention to provide an axial flow stage that, while capable of high energy transfer to a fluid, nevertheless incorporates relatively simple blade design.

It is a further object of the present invention to provide an axial flow stage having greater flexibility in its design for the purpose of obtaining a wider range of efficient performance while maintaining higher energy transfer.

It is still a further object of the present invention to provide, at any given radial distance from the rotor axis, blade sections of the main and auxiliary blades that cooperate while providing freedom in the circumferential and axial spacing between the first and second plurality of blades.

It is yet a further object of the present invention to provide an axial flow apparatus capable of high energy transfer utilizing two sets of blades, the leading edges of each set of blades being axially displaced from the leading edges of the outer set while the trailing edges of the first set are non-parallel to the leading edges of the second set, the second set of which operate as auxiliary blades and rotate in unison with the first set of blades.

It is still another object of the present invention to provide an axial flow stage capable of high energy transfer to a fluid wherein auxiliary blades are utilized to increase the energy transfer of the stage without the use of high and inefficient blade speeds.

These and other objects of the present invention will become apparent to those skilled in the art as the description thereof proceeds.

Briefly, in accordance with the embodiment chosen for illustration, an axial flow stage is provided incorporating a first set of blades, which I shall call the main blades, that are mounted upon a rotor or hub and extend radially therefrom to a housing forming an axial passageway between the rotor and housing. The main blades may be formed of conventional airfoil shape of the type found in compressors, pumps, and blowers and are warped or twisted from the root to the tip. A set of auxiliary blades is positioned downstream from the main blades without intervening stationary vanes; each auxiliary blade is also of conventional or foil-like cross section.

The auxiliary blades at the hub or root are positioned relative to the plane of rotation of the blades such that a line extending from the blade tip to the trailing edge forms an angle of greater than 90° with the plane; further, the auxiliary blades always exhibit a trailing edge at the root that points into the direction of rotation.

The present invention may more readily be described by reference to the accompanying drawings, in which:

FIG. 1 is a front elevational view of an axial flow stage constructed in accordance with the teachings of the present invention.

FIG. 2 is a cross-sectional view of the apparatus of FIG. 1.

FIG. 3 shows successive cross sections of a main blade of the apparatus of FIGS. 1 and 2.

FIG. 4 shows successive cross sections of an auxiliary blade of the apparatus of FIGS. 1 and 2.

FIG. 5 is a top view of a main blade and a auxiliary blade showing the non-parallel relationship of the trailing edge of the former relative to the leading edge of the latter.

FIG. 6 is a perspective view of the apparatus of the present invention, without the housing, showing the relationship between the main and auxiliary blades.

Referring now to the drawings, the apparatus of the present invention contemplates the utilization of a housing **10** in which a rotor **11** is mounted; the rotor and housing are coaxial to thereby define an axial flow passageway **14** therebetween. The rotor **11** supports a first plurality of blades **15** which may be referred to as main blades. Each of these extend radially from its root section **17** at the rotor **11** to a point at its tip **18** adjacent the inner wall **19** of the housing **10.** The blades **15** are circumferentially spaced about the rotor and incorporate a conventional airfoil-like section to be described more fully hereinafter.

Axially displaced from the main blades **15** is a second plurality of blades **20** which may be referred to as auxiliary blades. There are no stationary vanes between the main and auxiliary blades. The blades **20** also extend from their respective root sections **21** at the rotor **11** to a tip portion **22** which may or may not be adjacent the inner wall **19** of the housing **10.** In the embodiment chosen for illustration, both the main blades and the auxiliary blades are fixed in their respective positions relative to each other as shown; it will be apparent to those skilled in the art that the respective blades may be made adjustable in their circumferential, axial, and pitch positions. The auxiliary blades may be circumferentially displaced relative to the main blades and the leading edges **23** of the auxiliary blades **20** may be positioned ahead of the trailing edges **24** of the main blades **15**; however, it may be seen that trailing edges **24** are angled with respect to, or are not parallel to, the leading edges **23**. The non-parallel relationship of the leading edges **23** and trailing edges **24** may be stated differently; for example, the leading edges **23** of the auxiliary blades are displaced relative to the trailing edges **24** of the main blades, in the circumferential direction, in such a way that the distance between the two edges changes as the blades extend radially. The rotor may be constructed to permit axial and circumferential displacement of the main and auxiliary blades relative to each other.

With specific reference to FIG. **3**, the successive cross sections of the main blades **15** is shown. The direction of blade travel is indicated by the arrow **25** while the cross section of the blade **15** at the hub **11** is indicated at **27**. The blade is warped as it extends radially from the hub as may be seen by the cross section **29** at the approximate midpoint and the cross section **31** at the blade tip. Lines **27***a*, **29***a*, and **31***a* have been drawn from the leading to the trailing edges of the cross sections **27**, **29** and **31** respectively. A line **30** is provided to represent an imaginary plane of rotation of the blade **15**; the line **30** has been displaced to the right in FIG. **3** to facilitate the following description of the angular relationships involved. It may be seen that the cross section **27** has a line **27***a* extending from the tip to the trailing edge that forms an angle θ with the imaginary plane of rotation **30**. As the blade **15** extends from the root to the area of the cross section **29**, the line extending from the tip to the trailing edge thereof **29***a* forms an angle θ' with the plane of rotation **30**. The tip portion of the blade **31** and the line extending from the leading to the trailing edges thereof **31***a* form an angle θ'' with the plane of rotation **30**. It is apparent that the twisting or warping of the blade **15** causes the angle θ to decrease as the blade extends from the root to the tip thereof.

With reference to FIG. **4**, the successive cross sections of the auxiliary blade **20** are shown. The auxiliary blade **20** moves in the same direction as the main blades and incorporates an airfoil-like cross section throughout its length. The cross section **32** adjacent the hub **11** includes a trailing edge that points into the direction of travel of the blade. The blade **20** is warped as it extends radially outwardly from the hub as evidenced by the cross section **34** at the approximate midpoint thereof and the cross section **36** at the blade tip. As mentioned previously, the auxiliary blade **20** may be foreshortened and need not extend to a position adjacent the inner wall **19** of the casing **10**. Lines **32***a*, **34***a*, and **36***a* have been drawn from the leading to the trailing edges of the cross sections **32**, **34**, and **36** respectively. A line **40** is provided to represent an imaginary plane of rotation of the auxiliary blade **20**; the line **40**, similarly to line **30** in the previous figure, has been displaced to the right to facilitate the description of the angular relationship of the blade cross sections. The root cross section **32** includes a trailing edge that points substantially into the direction of travel of the blade as indicated by the arrow **25**. The line **32***a* drawn from the leading to the trailing edges of the cross section **32** forms an angle ϕ with the imaginary plane **40**. It may be noted that the angle ϕ is greater than 90°. The line **34***a* forms an angle ϕ' with the plane **40** while the line **36***a* forms an angle ϕ'' with the plane **40**. It may be seen that the angle ϕ decreases as the blade is twisted or warped as it extends from its root to its tip.

Referring now specifically to FIGS. **4** and **5**, the relationship of the main blades **15** and auxiliary blades **20** is shown with greater clarity. In this embodiment chosen for illustration, it may be seen that the auxiliary blades **20** have been shifted circumferentially with respect to the main blades **15**; further, the non-parallel relationship of the trailing edges **24** of the main blades **15** and the leading edges **23** of the auxiliary blades **20** is specifically shown in FIG. **5**. As mentioned previously, the main blades **15** are of conventional design and are generally of the reaction type blades commonly found in axial flow pumps, blowers and compressors. The auxiliary blades **20** each include conventional airfoil sections but are warped with the cross section of the blade adjacent the rotor **11**, or root section, having the trailing edge extend into the direction of rotation of the rotor. The auxiliary blades are designed to yield impulse-type energy transfer to the fluid flowing through the stage. The auxiliary blades may be foreshortened and extend radially from the rotor **11** for a length short of the distance from the rotor to the housing. In operation, the main and auxiliary blades are fixed on the rotor **11** with respect to each other and therefore rotate in unison without relative movement; further, no stationary vanes are positioned between the main and auxiliary blades, although such stationary vanes may be placed upstream or downstream of the stage.

The sections of the auxiliary blades in any one particular radial distance from the rotor axis are cooperative with the corresponding sections of the main blades, but the blades as a whole are independently shaped with the leading edges of the auxiliary blades non-parallel with the trailing edges of the main blades; that is, the distance between the leading and trailing edges of the auxiliary and main blades respectively, measured in a circumferential direction, varies as the blades extend radially from the hub.

It will be obvious to those skilled in the art that stationary vanes will be placed in the axial flow passageway **14**; the stationary vanes may be placed either ahead of or downstream of the main and auxiliary blades or perhaps may be placed in both positions but are not placed between the main and auxiliary blades. Energy transfer is essentially proportional to the velocity component in the peripheral direction which is created by the action of an impeller of the fluid machine. This energy transfer relationship exists notwithstanding the utilization of stationary vanes in the apparatus.

The utilization of main and auxiliary blades as described permits great values of such peripheral velocity components to be created; the energy transfer substantially exceeds that transfer available in the present devices of the same dimensions and same rotor rotational velocities. The present design also permits great flexibility in the choice of the distribution of rotary components over the radial distance between the rotor and the housing.

The cross sections of all blades referred to herein are essentially airfoil shaped. Generally, the term airfoil refers to cross sections widely used in aeronautics as well as in flow machinery design. These cross sections form elongated shapes with a thickness small by comparison to their length and with generally round leading edges with relatively sharp trailing edges. The thickness of the cross section gradually increases from the leading edge to a point somewhere between one-fourth and one-half of the length from the leading edge and then gradually diminishes toward the trailing edge. The configuration of the surrounding environment as well as a variety of conditions of the fluid flow will dictate the final shape of the airfoil. In certain applications, it may be possible to substitute planar sheets of construction material for the airfoils of greater thickness, for the sake of construction economy, in which case the warped sheets would have the shape of the center sections of corresponding airfoils. Therefore, as referred to herein, the term "airfoil" means the commonly accepted configuration of an airfoil as well as the simulated or approximated airfoil discussed above.

I claim:

1. In a fluid flow apparatus including a rotor, the axis of which extends along the direction of fluid flow, and having a housing surrounding said rotor, said housing extending along said rotor and radially spaced therefrom to define a fluid passageway between said rotor and housing a fluid energy boosting stage comprising:

a first plurality of circumferentially spaced energy adding blades secured to said rotor for movement in a plane of rotation, each having a leading edge and a trailing edge and each extending radially therefrom to adjacent said housing;

each of said first plurality of blades having substantially airfoil sections with the section at the blade root positioned relative to the plane of rotation of said blades such that a line extending from the leading to the trailing edge forms an angle with the plane of rotation that becomes progressively less at cross sections further from the blade root;

a second plurality of circumferentially spaced energy adding blades secured to said rotor for movement in a plane of rotation, each having a leading edge and a trailing edge and each extending radially

therefrom for rotation with said first plurality of blades said second plurality of blades being substantially circumferentially displaced from said first plurality of blades;

each of said second plurality of blades shaped and positioned independently from said first plurality of blades and having substantially airfoil sections, said sections at any given radial distance from the rotor axis cooperating with corresponding sections of the first plurality of blades to deflect the fluid flowing through the apparatus, the section of each of said second plurality of blades at the blade root adjacent said rotor positioned relative to the plane of rotation of said blades such that a cord line extending from the leading to the trailing edge forms an angle of greater than 90° with the plane, with the trailing edge pointing toward the direction of rotation of the blade, said angle becoming progressively less at sections further from the blade root.

the trailing edges of said first plurality of blades being angled with respect to the leading edges of said second plurality of blades.

2. The combination set forth in claim **1,** wherein said first and second pluralities of circumferentially spaced blades are positioned with the leading edges of said first plurality axially displaced from the leading edges of said second plurality and with said first and second pluralities of blades circumferentially displaced relative to each other.

3. The combination set forth in claim **1,** wherein each of said first plurality of blades extends radially from said rotor to adjacent said housing and wherein each of said second plurality of blades extends radially from said rotor and is shorter from its root to its tip than each of said first plurality of blades.

* * * * *