

Sept. 28, 1926.

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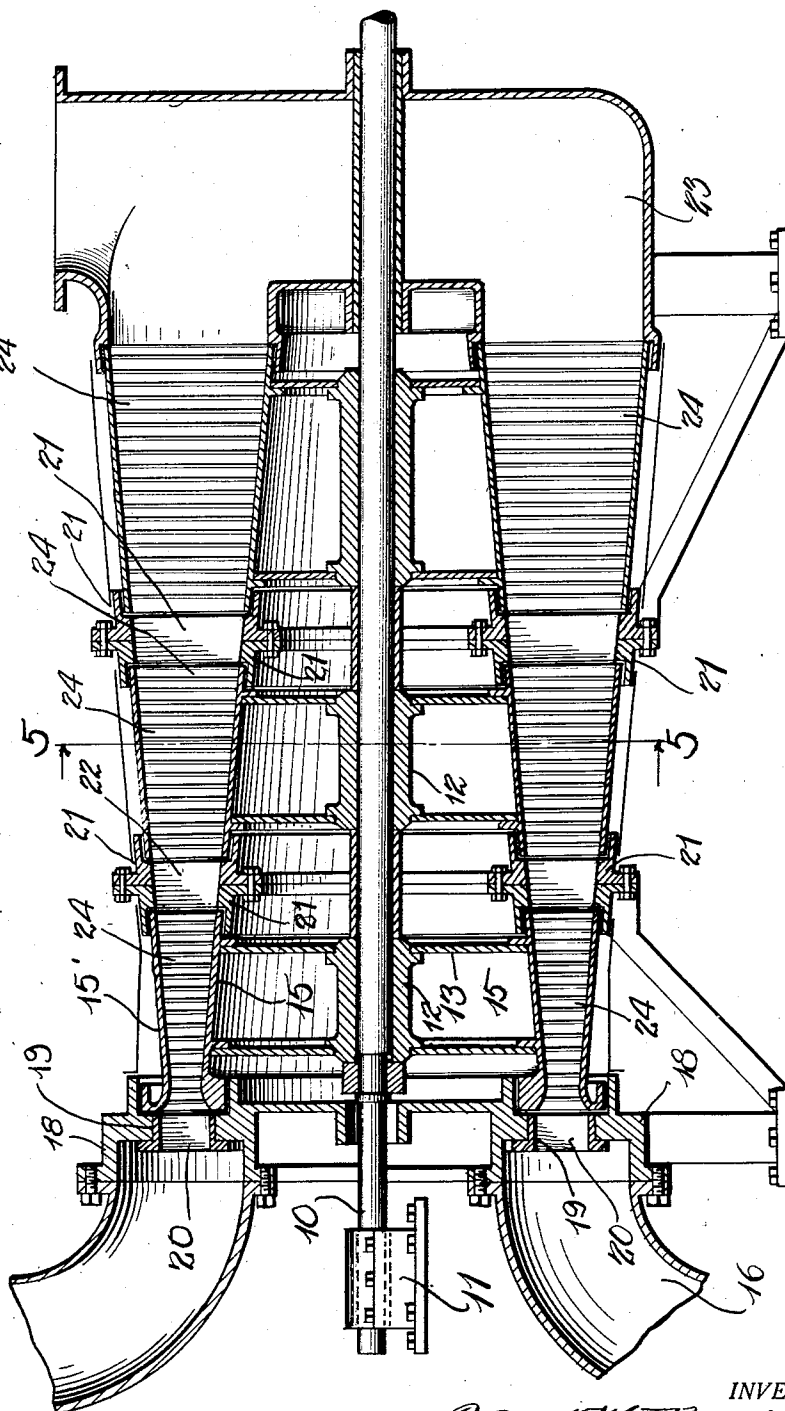
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TURBINE

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5 Sheets-Sheet 1

Fig. 1.



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Fig. 3.

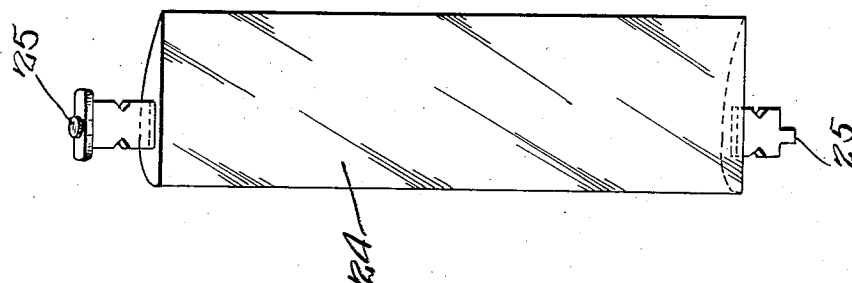
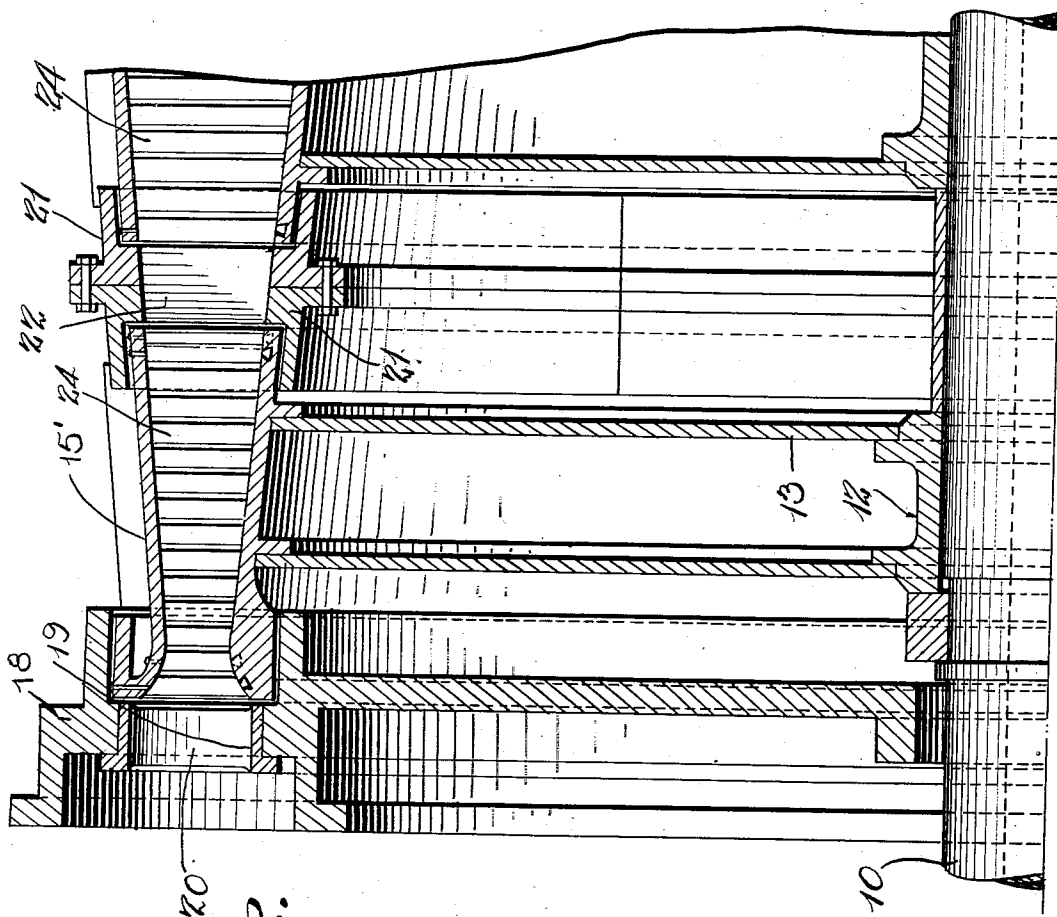


Fig. 2.

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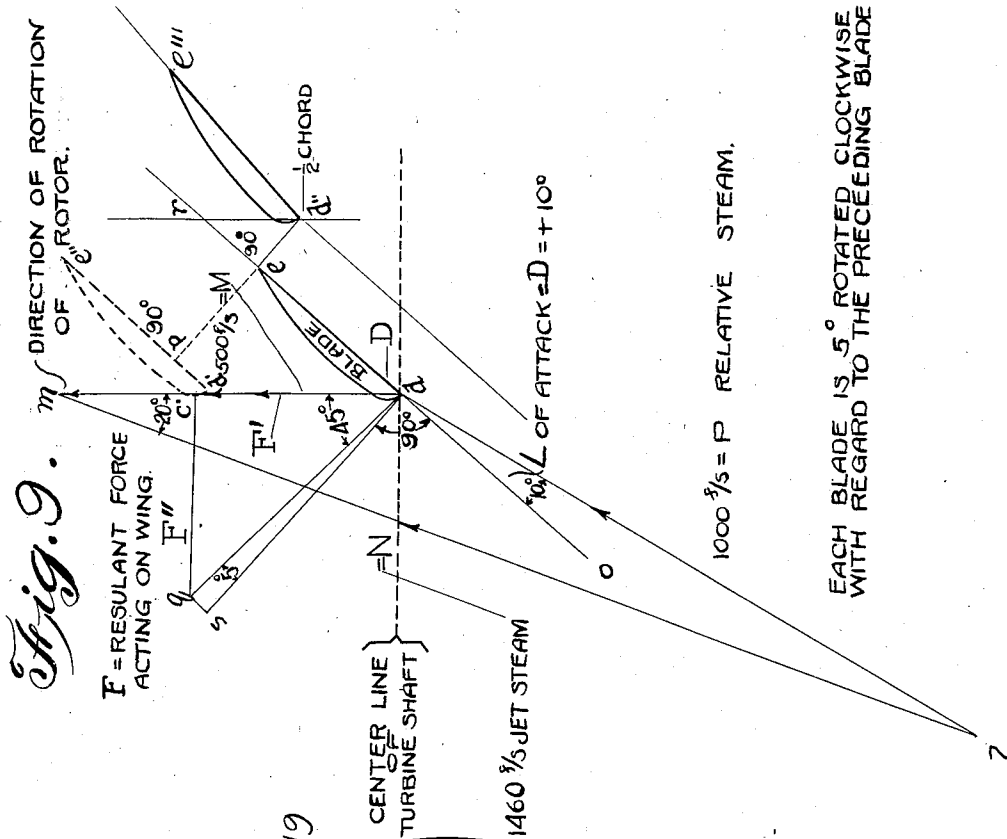
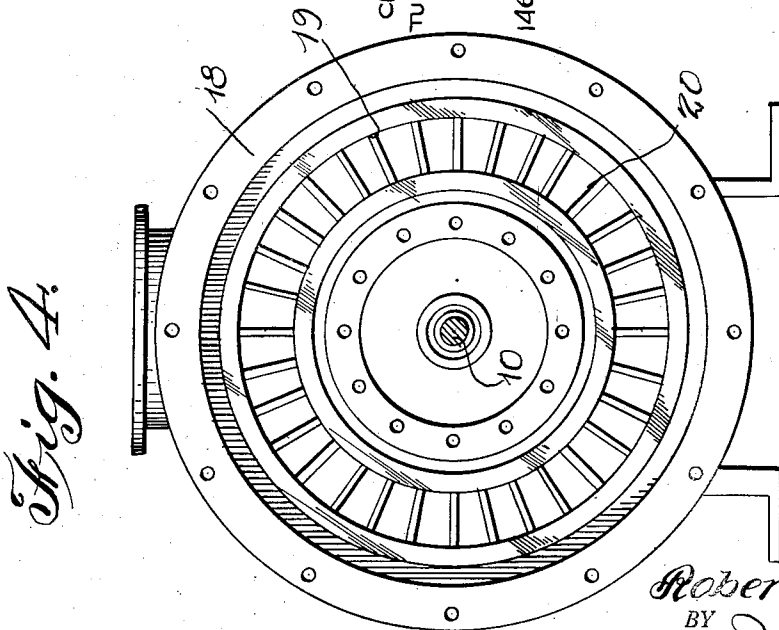
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5 Sheets-Sheet 3



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Fig. 7.

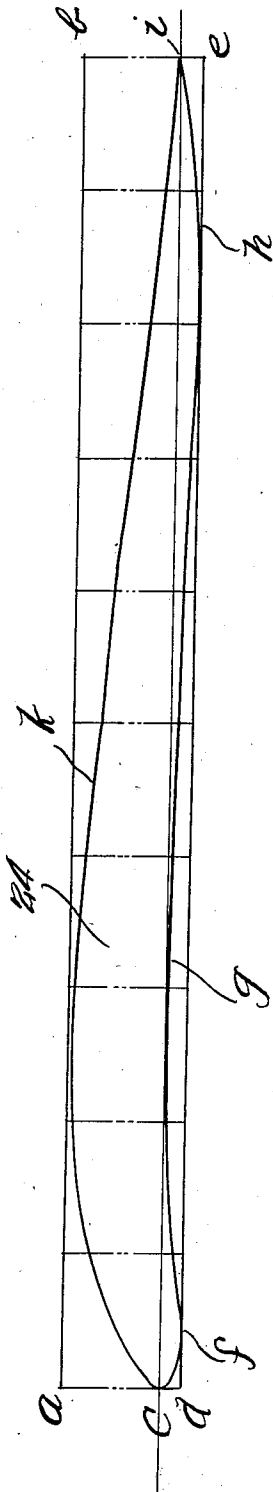


Fig. 6.

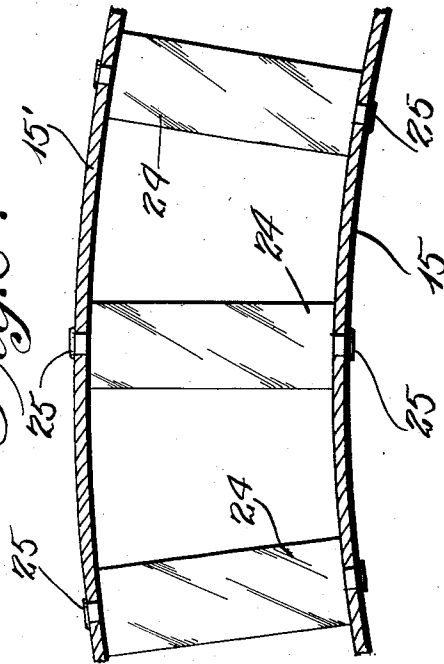
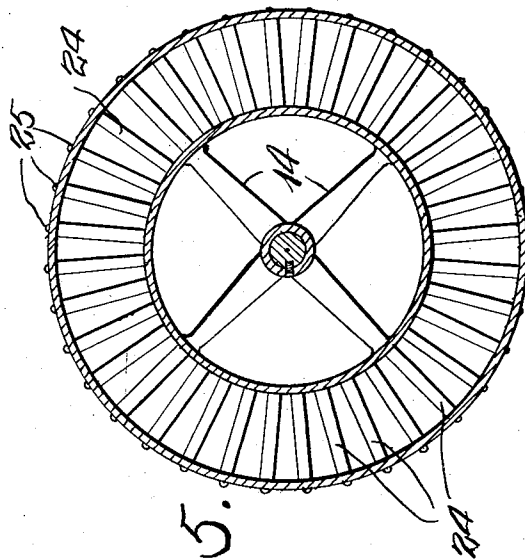


Fig. 5.

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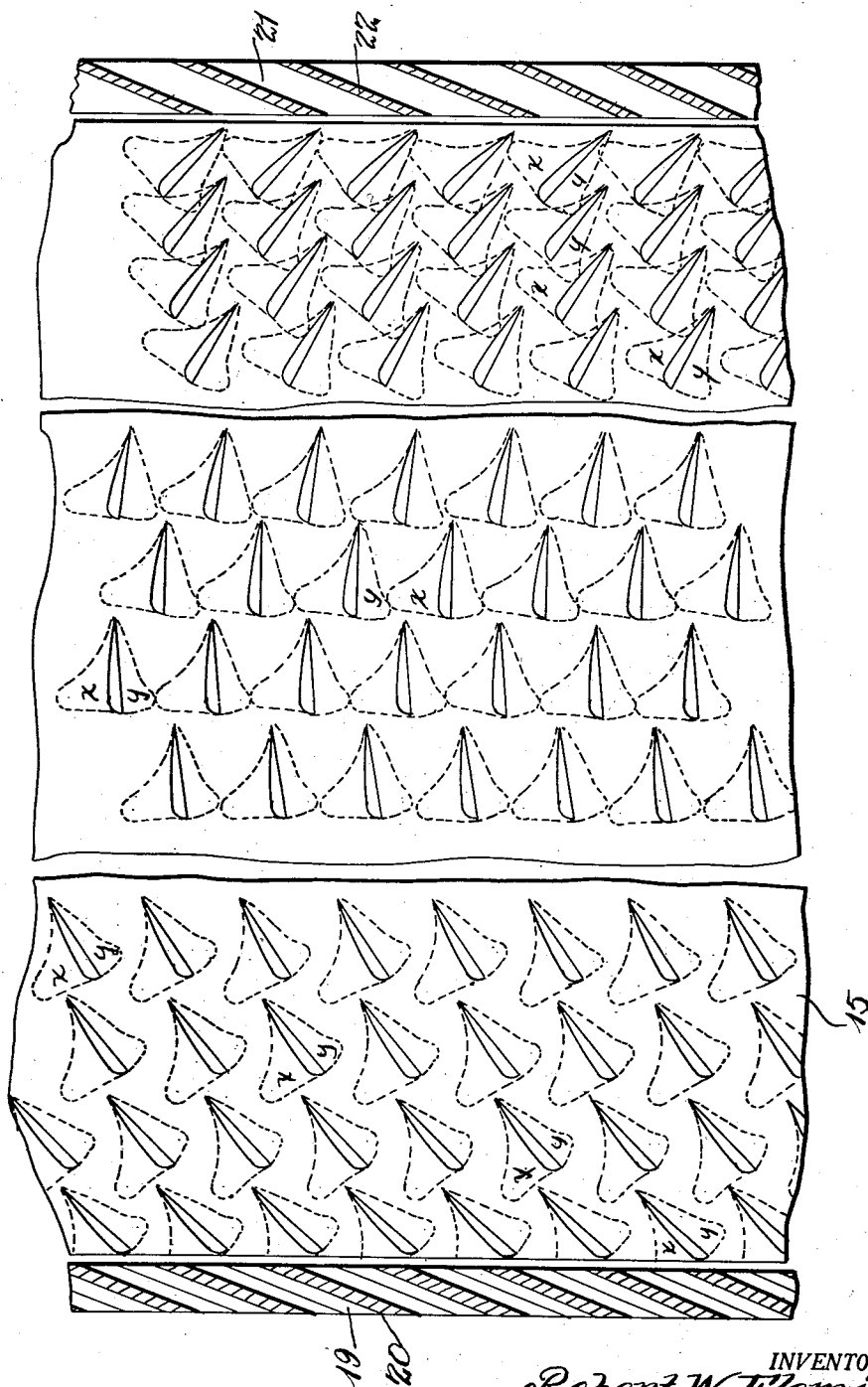
1,601,614

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5 Sheets-Sheet 5



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UNITED STATES PATENT OFFICE.

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TURBINE.

Application filed September 23, 1925. Serial No. 58,201.

This invention relates to steam turbines. Heretofore steam turbines have, in general, been of two characters. In one case the rotative effect has been produced by the inertia of movement of one or more steam jets striking against suitably designed buckets, such turbines being usually called impulse turbines. In the other case alternate rotor and stator elements, each having a multiplicity of blades have been employed, the reaction due to expansion and change of direction of flow of the steam producing the rotation of the rotor, such turbines being commonly known as reaction turbines.

It is well known that, in moving a properly formed aerofoil, such as an airplane wing, through the air a partial vacuum is produced above the aerofoil as well as pressure beneath and the upward tendency due to this partial vacuum produces what is known as "lift." ("Practical Aviation" by Kayward, American Technical Society, Chicago, Illinois, 1919.)

One principal object of this invention is to provide a turbine having blades and general construction designed to utilize, as fully as possible, this "lift."

This force called "lift" is generated by placing in a steady fluid flow a blade so designed in cross-section and so placed with regard to the flow that the pressure above the top of the blade is diminished while that below the blade is increased. There are then formed two areas of "influence." The one above the blade of low-pressure or suction, and that below the blade of high-pressure. To secure the best results consecutive and complementary blades must be so shaped and placed that these areas do not materially interfere with each other.

A second object of this invention is to increase the efficiency of a turbine by so designing, spacing, and placing the blades with regard to the steam flow and to one another that the low-pressure areas above the blades be utilized and not interfere with the high pressure areas below the blades or be disturbed by the blades themselves. Also that the losses due to eddy-currents, tip clearances, drag, and friction be reduced to a minimum, while at the same time producing the maximum useful work possible from the steam.

Wherever, in this application, any one of the words "steam, air, water, or any other gas or liquid or fluid substance" is used it is

to be taken to mean not only itself but also any one or more of the above named substances used to convert its potential power into work or assisting therein, by means of blades made fast to a rotor and acted upon by the substance.

With the above and other objects in view as will be hereinafter apparent, the invention consists in general of certain novel details of construction and combinations of parts hereinafter fully described, illustrated in the accompanying drawings and specifically claimed.

In the accompanying drawings like characters of reference indicate like parts in the several views, and:

Figure 1 is a longitudinal median section through a typical turbine constructed in accordance with this invention.

Figure 2 is an enlarged detail view of a portion of the inlet end of Figure 1, certain blades being omitted.

Figure 3 is a greatly enlarged perspective of one of the turbine blades removed from the rotor.

Figure 4 is an end view of the turbine from the inlet end thereof, the steam chest having been removed.

Figure 5 is a section on the line 5—5 of Figure 1.

Figure 6 is a detail showing a portion of Figure 5 the view being enlarged the better to show the blade mounting.

Figure 7 is a diagram showing the cross-sectional layout of one of the blades.

Figure 8 is a partially diagrammatic view showing the arrangement of the blades between the inlet and outlet ends of one stage in a turbine constructed in accordance herewith, the view being partially broken away to permit enlargement of the scale used.

Figure 9 is a diagrammatic view showing how the blades may be located relatively to each other and to the steam flow.

In the embodiment of the device here shown a three stage turbine has been illustrated as typical of the invention but it is to be understood that the number of stages may be increased or diminished according to the service to be performed without in any way affecting the principles of the invention.

Again, as will be seen later, certain angular relations between the entering steam and the blades as well as between the blades themselves are shown. In like manner these

relations are merely typical of one manner of carrying the invention into execution and may be varied in accordance with pressure and service conditions in accordance with the variations in form and as the angular relations are varied in the wings of an airplane, it being well known that airplanes intended for low speed and weight carrying have different and differently set wings for those intended for high speed.

Considering the construction of the form here shown in detail it will be seen that there is provided a shaft 10 which is, of course, supported in suitable bearings one of which is shown at 11. On this shaft, for each stage of the turbine, there is fixed thereto a hub 12 which may carry plates 13, as shown in Figures 1 and 2, or spokes 14, as shown in Figure 5. On the peripheries of these plates or the outer ends of these spokes, as the case may be, is mounted a frusto-conical rim 15 constituting the inner shroud or support for the inner ends of the turbine blades as will be presently explained. In the frusto-conical formation of this rim or inner shroud the taper of the frusto-cone is inwardly from the inlet end to the outlet end. The rim, hub and connecting members plates or spokes thus constitute a rotor wheel having a frusto-conical periphery tapering inwardly from the inlet end to the outlet end, at such an angle, slope or curve as will give the best steam expansion with this particular arrangement of blade as herein set forth.

Spaced from the rim 15 is an outer rim or shroud 15' likewise of frusto-conical form but tapering in the opposite direction also designed to give the best steam expansion. That is to say the outer shroud tapers outwardly from the inlet to the outlet end. By this means there is provided an annular space between the rims increasing in cross-sectional area from the inlet to the outlet end of the turbine.

An exception is to be noted to this in respect to the first stage wherein the inner and outer shrouds at the inlet end are flared away from each other to produce the equivalent of a Venturi effect. This is not necessary however.

At the inlet end of the turbine is provided a steam chest 18 which carries the nozzle supporting flange at the end adjacent the rotor, which consists of inner and outer concentric rings 19 connected by diagonally disposed partitions 20. Similarly, between each adjacent pair of stages there are provided nozzle rings each consisting of inner and outer rings 21 connected by diagonal partitions 22. At the outlet end of the turbine there is provided the usual exhaust chamber 23.

It will be obvious that suitable packing arrangements will be made in the construction of the device but it is not thought nec-

essary either to show or describe any such as these details form no part of the present invention.

All of the blades 24 are secured to both the inner and the outer shroud by fastenings 25 which may be of any preferred type. In this way the nozzle rings and casing form the stator while the shaft and the parts carried thereby form the rotor.

There will now be considered certain special features of the invention and first may be mentioned the peculiar cross sectional contour of the rotor blades. Each of these blades resembles in cross section the wing of an airplane and as typical of the manner in which such a cross section may be laid out reference is had to Figure 7. In this figure it will be seen that the chord distance ab is divided into ten equal parts and the greatest camber of the blade is at approximately 30% of this chord from the leading edge c along the chord line ci . The leading edge being that part of the blade farthest advanced up stream of the fluid flow. The nose of the blade is rounded and adjacent the leading edge on the under or pressure side of the blade a reverse camber f of small radius of curvature is formed just back of such edge. This reverse camber merges into a positive camber which again merges into a relatively long reverse camber h of relatively large radius of curvature near the trailing edge i , the latter being the point where the upper and lower blade surfaces meet. The upper or lift side of the blade has a continuous camber K . Such a blade closely resembles in cross section the United States Army standard wing curve No. 5 of 1919. Of course other blade sections may be used but all such will be of aerofoil type and will be generically described as such, meaning thereby a section wherein lift is developed by partial vacuum on the upper side of the blade and pressure on the under side of the blade. These vacuum and pressure areas are indicated at x and y respectively in Figure 8. The dotted lines indicating approximately the boundaries of these areas.

An important feature of the invention is illustrated particularly in Figures 8 and 9 and this feature relates to the peculiar arrangement of the blades so that the steam or other propelling fluid acts on these blades in such manner as to produce a substantially equal pressure on the pressure side of each blade and a substantially equal lift on the lift side of each blade. In addition, the blade arrangements must be such that, so far as possible, the lift or vacuum areas will not materially overlap and interfere with the pressure areas. Heretofore in turbines of this general description the blades have been placed so close together that the development of a lift area on the back of the blade has been impossible because of the

interference of the vacuum area on the top of the blade.

In other words, my blades are so placed around the periphery of the rotor wheel that complementary blades will not interfere with one another, each succeeding row of blades being also placed along the line of fluid flow so that the blades will be in the smoothest flow possible coming from the preceding row of blades. It will be noted that no so-called "guide blades" are used between the blades in this case and redirectional blades only used by the successive stages. As an example of the manner in which the positions of these blades are determined for this purpose let us assume as shown in Figure 9 that I have a turbine which we desire to have a blade peripheral linear velocity of 500 foot seconds represented by the length and direction of line dm . This force is in a plane perpendicular to the shaft center line of the turbine; as shown dotted. Next we decide that we wish the total resultant force which acts on the blade to be at an angle of 45 degrees with the plane of rotation of the blades. This resultant force is represented by line dq making an angle of 45 degrees with dm . This angle qdm may vary in accordance with amount of the component of dq which it is desired to have acting along line dm , this component being dc' . By decreasing the angle we increase dc' and decrease qc' and vice versa. In this particular case however we chose 45 degrees. The resultant force dq is made up of two forces, one parallel to the chord of the blade and represented by sq and called drag, the other perpendicular to the chord of the blade represented by sd and called lift. sq and sd are two sides of a parallelogram of forces and qd is the resultant, angle sdq being about 5 degrees in the case of the blade form chosen. Now we know that the lift sd is perpendicular to the blade chord (i. e., the blade chord in Figure 7), so we can now lay off line ode at 90 degrees with sd and for the convenience of construction assume that the forces on the blade act through the leading edge and thereby lay off the shape marked Blade with its nose at d and its chord along de .

We have chosen a blade form which gives the best results, or in other words, the maximum lift/drag ratio at an angle of attack of plus 10 degrees, therefore we lay off line dl making an angle of plus 10 degrees with the line of the blade chord edo . It is observed that this angle of attack of the blade may vary between minus 10 degrees and plus 30 degrees according to the conditions and in order to prevent the effect called burbling, or in other words, the formation of eddy currents, vortices or the production of a bow wave, and at the same time to obtain the maximum lift/drag ratio

and this permissible variation in the angle attack refers to all the rows of blades.

The line dl represents by its direction and length the velocity and direction of the steam flow relative to the blades. As generally accepted we take the relative steam flow to be of a velocity equal to twice the lineal peripheral velocity of the blades, or in this case 1000 foot seconds. By joining l and m we have line lm which represents by its length and direction the velocity and direction that is necessary for the jet or entrance steam. In this case it will be with the plane of rotation of the blades, or in other words of the rotor wheel.

In order to place blade $d'e''$ we advance along the rotor wheel making the distance dd' equal the chord length de and lay off chord $d'e''$ parallel to de and locating the leading edge of the blade at d' .

In order to lay off blade $d''e'''$, extend chord de indefinitely. Erect ed'' perpendicular to de at e . Draw rd'' parallel to dm and so that rd'' equals one half chord de , then draw $d''e'''$ so that it will make 5 degrees with line ode , or in other words so that the chord of blade $d''e'''$ is rotated 5 degrees clockwise from chord of blade de . d'' is then the nose of the new blade and $d''e'''$ equals de on its chord, which gives the set of the next row blades. In like manner the blades may be spaced and each row may be angularly displaced 5 degrees clockwise from the preceding row. By continuing this process it will be found that the blades will take successive positions as illustrated in Figure 8. As the steam or other fluid leaves the last row of blades, it is directed through another set of nozzles shown at 21 in Figure 8 having the same inclination relative to the blades of the second stage of the rotor as the nozzles at 19 have to the blades of the first stage.

It is to be understood that this is only one typical example in the manner in which these blades may be layed out and positioned, the example being given with certain assumption including certain blade peripheral linear velocity of 500 foot seconds. It is of course obvious that the same process may be used with other velocities as well as with other nozzle angles and directions of attack, the theoretical determination of the proper velocities and angles being attained in the well known manners set forth in the various text books on aviation and aerodynamics. And it is not accordingly deemed necessary to enter further into the theory involved since the action of known viscous fluids on aerofoils is well known.

As the fluid enters the inclined nozzles it is given a direction of flow and encounters the first series of blades at the left as shown in Figure 8. Some of the fluid passing above and some beneath. The upper sur-

faces of the blades are of larger area than the lower surfaces. This together with its shape will cause a reduced pressure on the upper side of the blades and an increased pressure below the blades. These pressures being diagrammatically illustrated by the dotted curve lines in Figure 8 the position and shape of the blades being such that these pressure areas interfere as little as possible with each other. After the fluid has passed in succession over all the series of blades in the first stage of the rotor its direction is changed by the stator nozzles 22 and delivered to the second stage rotor and its action is repeated and so on through all the turbine stages.

Having thus described the invention, what is claimed as new, is:

1. In a turbine, a rotor, blades attached thereto and arranged in successive rows, the second row taking the fluid from the first row, each blade having an aerofoil cross section and set at an angle of attack of the stream flow such that a partial vacuum will be formed on its inactive surface and a pressure on the active surface.
2. In a turbine, a rotor, a plurality of circumferential rows of turbine blades, the forward row set at an angle of attack of the stream flow of between minus 10° and plus 30° and the following row or rows having their cord lines set at an angle to the cord lines of the preceding row.
3. A turbine comprising a rotor in a plurality of stages, each stage having a plurality of circumferential rows of blades having an aerofoil cross section with the leading row of blades on each stage set at an angle of attack of the stream flow and each of the succeeding circumferential rows of blades set at an angle of attack similar to that of the preceding row whereby a smooth stream line flow from one row of blades to the succeeding row is obtained.
4. A turbine blade having an aerofoil cross section, and set at an angle of attack of the stream flow of between minus 10 degrees and plus 30 degrees, and means to direct a stream of elastic fluid against said blade.
5. A turbine blade having a cross sectional contour similar to the standard Army aeroplane wing designed to produce a partial vacuum on its inactive surface under the influence of a stream of elastic fluid impinging upon its active surface, and means to direct a stream of elastic fluid against said blade.
6. A turbine blade having a cross sectional contour similar to the standard Army aeroplane wing designed to produce a partial vacuum on its inactive surface and a pressure on its active surface under the influence of a stream of elastic fluid impinging upon its active surface, and means to direct a stream of elastic fluid against said blade.
7. In a turbine, a rotor including a series of circumferential rows of blades arranged to take the same fluid in succession, the second row after the first several of the blades having an aerofoil cross section.
8. In a turbine, a rotor including a series of circumferential rows of blades each having an aerofoil cross section, the blades of each successive row having their chord lines set at successively greater angles to the chord lines of the first row.
9. In a turbine, a rotor including a series of circumferential rows of blades each having an aerofoil cross section, the blades of each row having their chord lines set at an angle to the chord lines of the preceding row and offset circumferentially to the blades of said preceding row.
10. In a turbine, a rotor including a series of circumferential rows of blades each having an aerofoil cross section, and a steam chest having a series of angularly disposed nozzles leading therefrom and arranged to direct elastic fluid against the first row of said blades.
11. In a turbine, a rotor including a series of rows of blades each having an aerofoil cross section, the blades of each row having their chord lines set at an angle to the chord lines of the preceding row, and a steam chest having a series of angularly disposed nozzles leading therefrom and arranged to direct elastic fluid against the first row of said blades.
12. In a turbine, a rotor including a series of rows of blades each having an aerofoil cross section, the blades of each row having their chord lines set at an angle to the chord lines of the preceding row and offset circumferentially to the blades of said preceding row, and a steam chest having a series of angularly disposed nozzles leading therefrom and arranged to direct elastic fluid against the first row of said blades.
13. In a turbine, a rotor including a series of rows of blades each having an aerofoil cross section, the blades of each row having their chord lines set at an angle to the chord lines of the preceding row, the angles at which each row of blades is set with reference to the angles of the preceding row being such as to produce equal effects on each row of blades.
14. In a turbine, a rotor including a series of rows of blades each having an aerofoil cross section, the blades of each row having their chord lines set at an angle to the chord lines of the preceding row, the angles at which each row of blades is set with reference to the angles of the preceding row being such as to produce a smooth stream line flow from one row of blades to the succeeding row.
15. In a turbine, a rotor including a series

of rows of blades each having an aerofoil cross section, the blades of each row having their chord lines set at an angle to the chord lines of the preceding row and offset circumferentially to the blades of said preceding row, the angles at which each row of blades is set with reference to the angles of the preceding row being such as to produce equal effects on each row of blades.

16. In a turbine, a rotor including a series of rows of blades each having an aerofoil cross section, the blades of each row having their chord lines set at an angle to the chord lines of the preceding row and offset circumferentially to the blades of said preceding row, to cause a smooth stream line flow from one row of blades to the succeeding row.

17. In a turbine, a rotor including a series of rows of blades spaced circumferentially of the turbine and each having an aerofoil cross section arranged to produce a vacuum area on the inactive side of the blade and a pressure area on the active side of the blade, the circumferential spacing of the blades in each row being such as to prevent material interference between the vacuum and pressure areas, all blades of each stage of the turbine being mounted on a common shroud.

18. In a turbine, a rotor including a series of rows of blades spaced circumferentially of the turbine and each having an aerofoil cross section arranged to produce a vacuum area on the inactive surface of the blade and a pressure area on the active surface of the blade, the circumferential spacing of the blades in each row being such as to prevent material interference between the vacuum and pressure areas, the blades of each row having their chord lines set at an angle to the chord lines of the preceding row.

19. In a turbine, a rotor including a series of rows of blades spaced circumferentially of the turbine and each having an aerofoil cross section arranged to produce a vacuum area on the inactive side of the blade and a pressure area on the active side of the blade, the circumferential spacing of the blades in each row being such as to prevent material interference between the vacuum and pressure areas, the blades of each row having their chord lines set at an angle to the chord lines of the preceding row and offset circumferentially to the blades of said preceding row.

20. In a turbine, a rotor including a series of rows of blades spaced circumferentially

of the turbine and each having an aerofoil cross section arranged to produce a vacuum area on the inactive side of the blade and a pressure area on the active side of the blade, the circumferential spacing of the blades in each row being such as to prevent material interference between the vacuum and pressure areas, and a steam chest having a series of angularly disposed nozzles leading therefrom and arranged to direct elastic fluid against the first row of said blades.

21. In a turbine, a rotor including a series of rows of blades spaced circumferentially of the turbine and each having an aerofoil cross section arranged to produce a vacuum area on the inactive side of the blade and a pressure area on the active side of the blade, the circumferential spacing of the blades in each row being such as to prevent material interference between the vacuum and pressure areas, the blades of each row having their chord lines set at an angle to the chord lines of the preceding row, and a steam chest having a series of angularly disposed nozzles leading therefrom and arranged to direct elastic fluid against the first row of said blades.

22. In a turbine, a rotor including a series of rows of blades spaced circumferentially of the turbine and each having an aerofoil cross section arranged to produce a vacuum area on the inactive side of the blade and a pressure area on the active side of the blade, the circumferential spacing of the blades in each row being such as to prevent material interference between the vacuum and pressure areas, the blades of each row having their chord lines set at an angle to the chord lines of the preceding row, the angles at which each row of blades is set with reference to the angles of the preceding row being such as to produce equal effects on each row of blades.

23. In a turbine, a rotor including a series of rows of blades spaced circumferentially of the turbine and each having an aerofoil cross section arranged to produce a vacuum area on the inactive side of the blade and a pressure area on the active side of the blade, the circumferential spacing of the blades in each row being such as to prevent material interference between the vacuum and pressure areas a smooth stream line flow from one row of blades to the succeeding row.

In testimony whereof he affixes his signature.

ROBERT WALTON FLEMING.