Oct. 9, 1923. 1,469,925

A. T. KASLEY

TURBINE

Filed Dec. 12, 1921 3 Sheets-Sheet 1

Fig. 1.

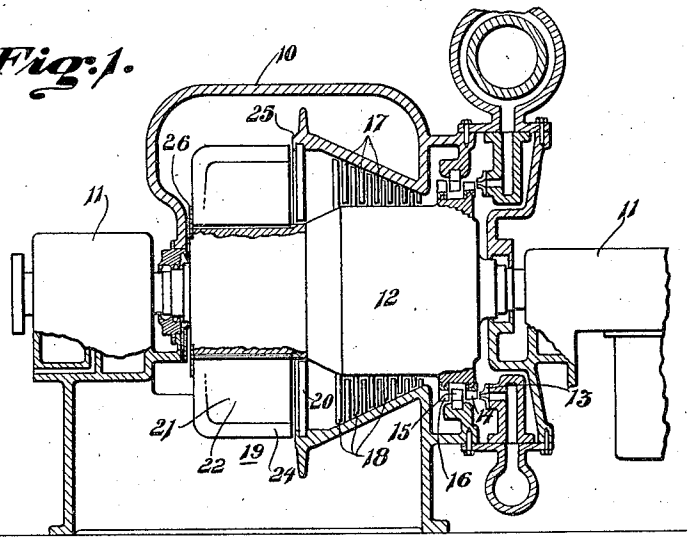
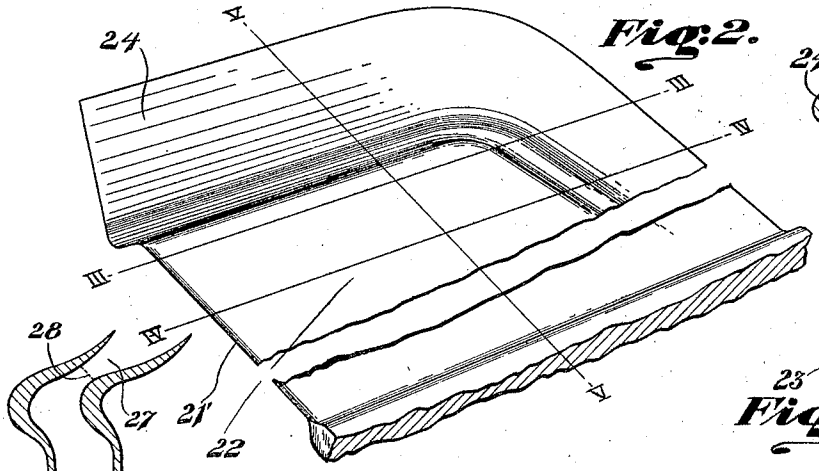


Fig. 2.



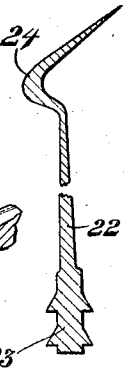


Fig. 5.

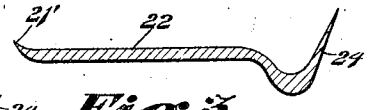


Fig. 3.

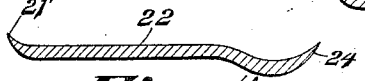


Fig. 4.

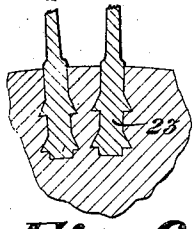


Fig. 6.

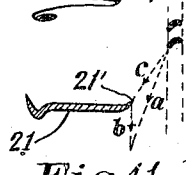


Fig. 11.

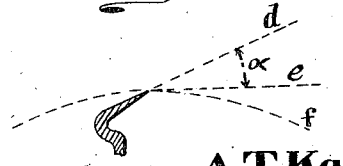


Fig. 12.

WITNESSES:

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Oct. 9, 1923. 1,469,925

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TURBINE

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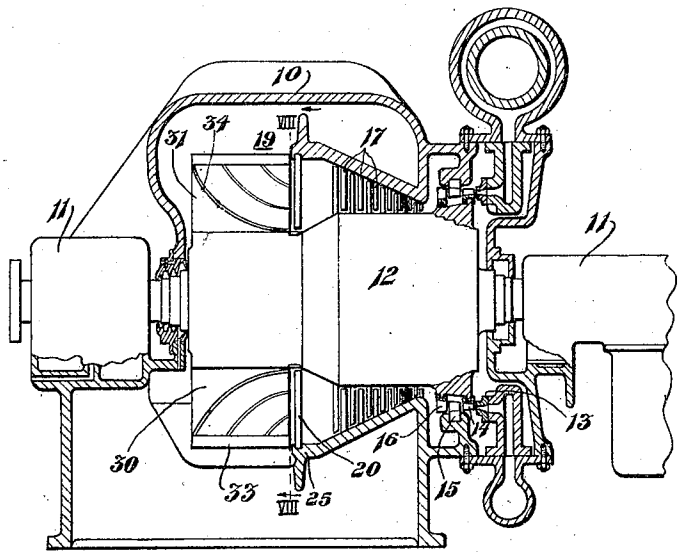


Fig. 7.

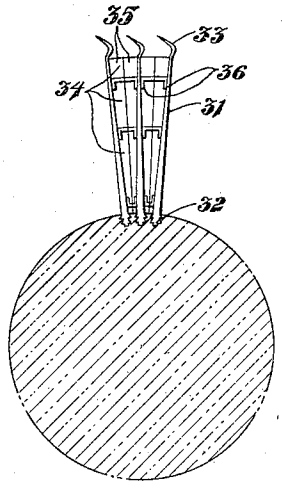


Fig. 8.

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Filed Dec. 12, 1921 3 Sheets-Sheet 3

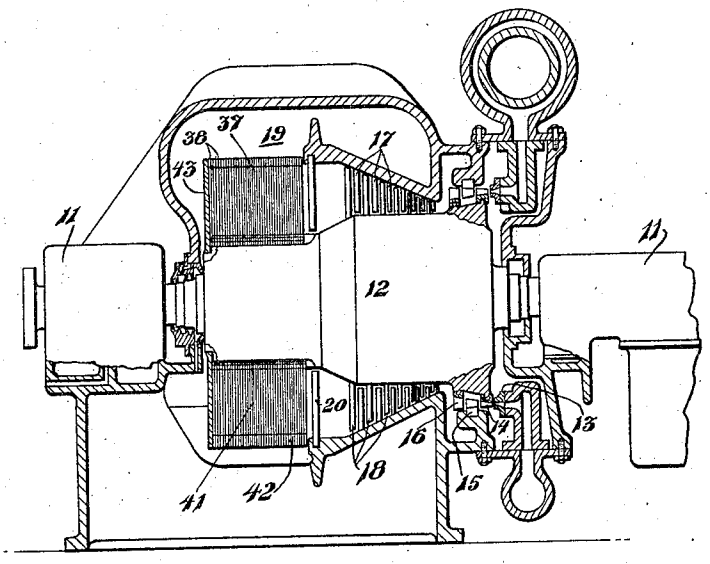


Fig. 9.

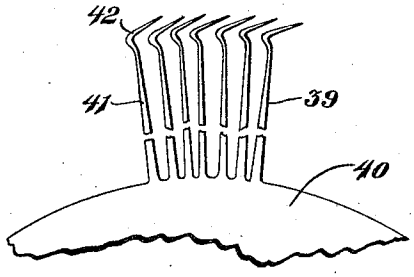


Fig. 10.

WITNESSES:

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Patented Oct. 9, 1923. 1,469,925

UNITED STATES PATENT OFFICE.

ALEXANDER T. KASLEY, OF ESSINGTON, PENNSYLVANIA, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA.

TURBINE.

Application filed December 12, 1921. Serial No. 521,872.

To all whom it may concern:

Be it known that I, ALEXANDER T. KASLEY, a citizen of the United States, and a resident of Essington, in the county of Delaware and State of Pennsylvania, have invented a new and useful Improvement in Turbines, of which the following is a specification, this application being a continuation in part of my application, Serial No. 486,517, filed July 21, 1921.

My invention relates to steam or elastic-fluid turbines, and more particularly to low-pressure blading of the relatively wide type which receives steam or elastic fluid laterally and discharges it peripherally, and it has for its object to provide low-pressure blading of this character which shall be so designed as to operate with little, if any, vibration or deformation due to centrifugal bending stresses and which shall be capable of being easily and cheaply manufactured.

A further object of my invention is to provide, in connection with blading of the character designated, means which shall deflect the steam or elastic fluid from an axial toward a radial direction and which shall reinforce the blading structure.

In the drawings, forming a part of this application, Fig. 1 is a sectional view of a turbine with one form of my improved blading applied thereto; Fig. 2 is a perspective view on a larger scale of one of the blades shown in Fig. 1; Figs. 3, 4 and 5 are sectional views taken along the lines III—III, IV—IV and V—V respectively of Fig. 2; Fig. 6 is a detailed view showing a slightly modified form of blading; Fig. 7 is a view similar to Fig. 1, but showing a modified form of low-pressure blading; Fig. 8 is a sectional view taken along the line VIII—VIII of Fig. 7 and viewed in the direction of the arrow; Fig. 9 is a view similar to Fig. 1, but showing a still further modified form on my improved low-pressure blading; Fig. 10 is a detail view of a portion of the blading structure employed in Fig. 9; and Figs. 11 and 12 are diagrammatic views illustrative of certain features of my invention.

In the construction of steam or elastic fluid turbines, particularly of the large high-speed type, it has heretofore been found to be necessary to provide the last row or group of rows of moving blades with large leaving angles in order to handle the large volumes of low-pressure steam or elastic fluid for the reason that, for a given speed, the blade height is limited by the allowable stress of the material of which the blade is made; and, of course, as the leaving angles are made larger the efficiency of the blading declines.

In the construction of high-power single unit turbines, difficulties have been met with on account of excessive blade speeds due to the large rotor or disk diameter and the last row of tall moving blades necessary to pass the elastic fluid if the latter is to be discharged without too much residual energy. In the application of Henry F. Schmidt, Serial No. 482,768, filed July 6, 1921, and assigned to the Westinghouse Electric and Manufacturing Company, there is disclosed and claimed relatively wide last-row blading which discharges peripherally or peripherally and laterally, thereby making it possible to increase the exit area by increasing the blade width instead of the blade height, as formerly, and making it possible to provide high-power turbine units without encountering excessive blade speeds.

The blading disclosed and claimed in said application of Henry F. Schmidt is relatively wide and it is capable of handling large volumes of low-pressure elastic fluid or steam and of discharging the latter at small angles, thereby resulting in high blade efficiency, in improved turbine performance, and in making it practicable to construct large, high-speed turbines which operate with high efficiency. In the Schmidt turbine, adequate discharge area at small leaving angles is provided by having the steam or elastic fluid discharged peripherally or at the tips, thereby rendering it possible to make the discharge area equal at least to the area swept by the inlet sides of the blades merely by choosing a width of blade which will serve this purpose. It is characteristic of the Schmidt type of low-pressure or exhaust moving blades that they are relatively much wider than corresponding blading of the axial-flow type. In other words, the direction of flow of steam between the blades is changed and the steam is expanded and discharged peripherally so that adequate discharge area may be provided, with the preservation of efficient discharge angles,

merely by choosing a proper width. It will be obvious that a change in width is not accompanied by any change in unit stress in the blading, whereas, with axial-flow blading, an increase in the discharge area is secured by making the blades taller or by choosing larger discharge angles. As axial-flow blading is made taller the centrifugal stresses increase until a point is reached beyond which it is not safe to go and further discharge area may be provided only by gauging or providing the blades with larger discharge angles which produce less efficient blading for the reason that the larger the discharge angle the larger becomes the axial component of the reactive effort. The capacity of axial-flow blading to handle large volumes of elastic fluid efficiently is limited which is not true of blading of the wide type disclosed herein and in the Schmidt application aforesaid. Since width is a material factor in providing adequate discharge area with the latter type of blading, it is to be understood that the terms "wide" and "relatively wide" are used in this specification and the appended claims to designate blading of this character which differs markedly over axial-flow blading heretofore used. This type of blading is also capable of converting a greater portion of the kinetic energy of the elastic fluid or steam into useful work than can be converted by blading of the ordinary type for the reason that, with the peripherally-discharging type of blading, the reactive force or effort is applied to portions of the blading moving at high effective blade speeds.

It is the object of my invention to improve the type of low-pressure blading disclosed in the application of Henry S. Schmidt, aforesaid, so that it may be more easily and cheaply made and may be of such a design as to secure better operation. The contour of my improved blade is such that it may be easily rolled or drop-forged, or a row of blades may be built up of laminae or sections and secured together in any suitable manner. Better operation is secured by so designing each blade that the center of gravity thereof falls approximately midway of the circumferential thickness thereof, whereby centrifugal bending stresses and possibly resulting deformation or vibration of the blades are avoided.

Referring now more particularly to the drawings for a detailed description of my invention, in Fig. 1, I show a turbine comprising a cylinder or casing 10 having bearings 11 of any suitable type for appropriate journal portions of the rotor 12. Any suitable energy-abstracting elements are carried by the casing and rotor for abstracting energy by the expansion of steam or elastic fluid. For example, I show a stage 12 of the multivelocity impulse type, comprising one or more nozzles 13 adapted to discharge steam or elastic fluid at high velocity into the first row of impulse blades or buckets 14 from which the steam or elastic fluid passes to the re-directing blades or vanes 15 to be re-directed against the second row of impulse blades or buckets 16, followed by a series of fractional expansion stages comprised by the stationary and moving rows of blades 17 and 18 carried by the cylinder or casing 10 and by the rotor 12, respectively. The steam or elastic fluid undergoes pressure-velocity conversion in the nozzle or nozzles 13 and the velocity energy is abstracted in two steps by the impulse blades or buckets 14 and 16. Thereafter, the steam is fractionally expanded in the stages comprised by the stationary and moving rows of blades 17 and 18, and the steam then passes from the last row of moving blades 18 at a low pressure for action upon the blading of my improved form of low-pressure stage 19 comprising a row of guide blades 20 carried by the cylinder or casing 10 and a row of relatively wide blades 21 carried by the rotor 12.

The guide blades 20 discharge steam or elastic fluid between the blades 21 and the steam or elastic fluid is discharged from the latter peripherally or radially and laterally or axially. Each blade 21 has an inner radial or plane portion 22 having a suitable root portion 23 for attachment to the rotor 12. The radial or plane portions 22 are arranged in approximately axial planes and constitute supports for the outer curved, spoon-outline, or trough-like portions 24 constituting energy-abstracting portions for the blades. The curved, spoon-outline, or trough-like portions 24 extend from the inlet sides of the blades across the tops thereof, around the rear corners, and thence inwardly; and, as illustrated in Figs. 1 and 2, the inwardly-extending portions may merge into the inner radial portions 22, although it is to be understood that the inwardly-extending curved portion may extend inwardly to any desired extent. This form of curved spoon-outline, or trough-like construction permits of the discharge of steam or elastic fluid both peripherally and laterally at small angles.

As shown in Fig. 1, the casing or cylinder 10 is provided with a portion 25 which, not only constitutes a support for the guide blades 20, but also serves to cover the outer portions of the inlet sides of the trough or spoon-outline portions 24 defining nozzle expanding passages between the blades, thereby preventing the cross-flow of steam or elastic fluid into the latter passages. A suitable plate 26 is secured to the rotor 12 and is arranged to cover the rear radial portions of the blades 21.

Each of the blades 21 is so designed that

its center of gravity falls substantially midway of the thickness thereof, thereby avoiding the development of centrifugal bending stresses which might tend to cause it to vibrate or be deformed.

The inlet edges 21′ of the blades 21 may be suitably inclined in accordance with the blade velocity, steam, or elastic fluid velocity, and the angle of discharge of the steam or elastic-fluid from the guide blades 20. See Figs. 2, 3, 4, and 11.

Referring to the velocity diagram shown in Fig. 11, the vector *a* represents the velocity and direction of discharge of motive fluid leaving the guide blades 20, the vector *b* represents the blade velocity, and the vector *c* represents the relative velocity of the motive fluid with respect to the blades 21. The inlet side 21′ should, therefore, be so curved as to be tangent to the incoming motive fluid, that is, to the vector *c*. In other words, the curvature of the inlet edges of the wide blades is determined by the direction and velocity of discharge from the guide blades and by the velocity of the moving blades.

In Fig. 6, I show a modified form of my blading in which the curved, or spoon-outline outer portions define expanding passages 27, a throat being indicated at 28, whereby the blading may be capable of not only handling large volumes of elastic fluid, but also of securing greater expansion thereof.

In Figs. 7 and 8, I show a further modified form of my improved peripherally-discharging, low-pressure turbine blading. In these views, I show a row of relatively wide blades 30 having inner radial or plane supporting portions 31 arranged in axial planes and adapted to be secured to the rotor 12 by any suitable root connection 32. Curved, or spoon-outline portions 33 are carried at the tips of the blades 30 and cooperate to define nozzle or expanding passages for the purpose of abstracting energy from steam or elastic fluid passing therethrough. Steam or elastic fluid is discharged between the inlet edges of the blades 30 by means of guide blades 20 in the manner heretofore described.

As the steam or elastic fluid enters between the blades 30 of Figs. 7 and 8 in substantially an axial direction and is discharged therefrom at the tips or periphery, it is desirable to provide deflecting means to secure a change in direction of flow of the steam with a minimum degree of eddying. Accordingly, I have provided each blade with a series of ribs 34 carried by the faces of the radial portions 31. Preferably, these ribs are made of curved angle sections secured to the radial or plane portions 31 of the blades in any suitable manner, as by spot-welding. The angle guide members or ribs 34 are provided with angle portions 35 which are adapted to contact, as shown in Fig. 8, to constitute partition or wall elements in order to divide and deflect the steam or elastic fluid for discharge through the passages defined by the curved, or spoon-outline portions 33; and, in order that the portions 35 may contact throughout the lengths of the guide members 34, it is necessary that such portions 35 shall be made of tapering width on account of the radial divergence of the blades. The portions 36 of the guide members 34 are adapted to be spot-welded to the radial portions 31 of the blades 30 in order to hold the guide members 34 in place. The guide members 34 are spot-welded to the blades 30 before the latter are assembled.

In Fig. 7, the cylinder or casing 10 is provided with a portion 25 which not only supports the fixed guide blades 20, but also covers the outward portions of the curved, or spoon outline portions 33 in the manner and for the purpose described in connection with Fig. 1.

In Figs. 9 and 10, I show a further modified form of wide blade 37 for the last stage 19. The wide blades 37 are composed of a plurality of laminations 38, having blade-forming portions 39 and hub-forming portions 40. The laminations 38 may be punched from any suitable sheet metal, either as single pieces or in sections. The laminations are piled together lengthwise of the rotor 10 so that the blade forming portions 39 register to constitute the wide blades 37. The blades 37 comprise inner radial supporting portions 41 and outer curved, spoon-outline, or trough-like energy-abstracting portions 42, arranged similarly to the corresponding portions of Fig. 7. In order to prevent side-spilling of steam or elastic fluid from the blades 37 and to assure the change in direction thereof so that it may be discharged peripherally, it is necessary to block the spaces between the blades; and, I have, therefore, provided a suitable blocking plate 43 for this purpose.

The laminated construction is advantageous in that it is possible to build up a blade structure of any suitable width economically and for the further reason that the resulting structure is stronger as the blade-forming portions 39 are integral with the hub-forming portions 40, thereby avoiding the use of ordinary root connections.

In all of the modifications aforementioned high blade efficiency is maintained by the preservation of small discharge angles. This will be apparent from diagrammatic Fig. 12, wherein the line *d*, tangent to the inner edge of the outer portion of the curved or spoon-outline portion, represents the direction of discharge of motive fluid and the line *e* is the tangent to the blade

tip circle *f*. The angle α between the lines *d* and *e* is the angle of discharge and it will be noted that it is relatively small.

Apparatus made in accordance with my invention operates as follows: Steam or elastic fluid is expanded in the higher pressure stages of the turbine and it is discharged therefrom into the last low-pressure stage 19, having the relatively wide moving row of reaction blading which receives the steam or elastic fluid flowing in substantially an axial direction and discharges it peripherally or in a radial direction or peripherally and laterally. The steam or elastic fluid is expanded and discharged from the nozzle passages, defined by the curved, spoon-outline, or trough-like portions of the wide blades, at small angles, the feature of discharging at small angles being possible due to the fact that the discharge area may be made sufficient merely by choosing a suitable width of blade.

It will be obvious to those skilled in the art that my new type of blade is capable of securing better turbine operation. My new blades are capable of handling large volumes of low-pressure, elastic fluid or steam, of expanding the elastic fluid or steam to low-pressures, of operating at high blade efficiency as the elastic fluid or steam is discharged at small angles and the reactive effort of the high velocity elastic fluid or steam is applied to the blade portions moving at high effective speeds, and of operating at high speeds as the discharge area is secured by increasing the blade width instead of height. By using my wide exhaust blading, it is therefore possible to construct large, high-speed turbine units and units which operate more efficiently than heretofore.

While I have shown my invention in a plurality of forms, it will be obvious to those skilled in the art that it is not so limited but is susceptible of various other changes and modifications without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be placed thereupon as are imposed by the prior art or as are specificially set forth in the appended claims.

What I claim is:

1. In an elastic-fluid turbine, a last row of moving blades having inner radial or plane portions and outer curved portions adapted to receive elastic fluid axially and to discharge it peripherally.

2. In an elastic-fluid turbine, a row of peripherally-discharging moving blades adapted to receive elastic fluid at one side, the center of gravity of each blade being disposed symmetrically with respect to the circumferential distribution of mass thereof.

3. A turbine blade having a radial portion and a curved tip-discharging portion, the center of gravity of the blade falling within the radial portion.

4. In an elastic-fluid turbine, a row of peripherally-discharging blades having inner radial portions and outer curved portions to provide for the discharge of elastic fluid at a small angle.

5. In an elastic-fluid turbine, a row of peripherally-discharging blades having inner radial portions and outer curved portions arranged to discharge elastic fluid at a small angle, and elastic-fluid or steam deflecting means cooperating with the radial portions of the blades.

6. In an elastic-fluid turbine, a low-pressure stage including a last row of relatively wide blades adapted to receive elastic fluid axially and to discharge it peripherally, each of the blades comprising an inner radial portion and an outer curved portion.

7. In an elastic-fluid turbine, a row of blades adapted to receive elastic fluid at one side and comprising inner radial and outer curved, energy-abstracting portions.

8. A turbine blade comprising an inner substantially plane portion and a curved, energy-abstracting portion at the tip.

9. A turbine blade comprising an inner radial portion and an outer spoon-outline or trough-like portion, the center of gravity of the blade falling within the radial portion.

10. A turbine blade comprising inner radial and an outer spoon-outline or trough-like portion, the center of gravity of the blade falling midway of the thickness of the radial portion of the blade, whereby centrifugal bending moments are avoided.

11. In an elastic-fluid turbine, a last row of moving blades, each comprising an inner radial portion and an outer spoon-outline or trough-like portion, the outer portions of the spoon-outline or trough-like portions defining passageways for the expansion of elastic fluid peripherally.

12. In an elastic-fluid turbine, a last row of moving blades having energy-abstracting outer portions and inner supporting portions therefor secured in position substantially in axial planes.

13. In an elastic-fluid turbine having a rotor, a last row of moving blades having energy-abstracting outer portions and inner supporting portions arranged substantially in axial planes and secured to said rotor throughout the width of said inner portions.

14. In an elastic-fluid turbine having a rotor, a last row of moving blades having outer, peripherally- or tip-discharging energy-abstracting portions carried by inner portions arranged in substantially axial planes and secured throughout the width thereof to said rotor.

15. In an elastic-fluid turbine, the combination of a last row of blades adapted to

receive elastic fluid at one side and to discharge it at the tips, each blade having an outer curved portion to provide for the discharge of elastic fluid at a small angle and an inner substantially plane portion, and contacting guide ribs or partition members carried by the blades to define guide means for the elastic fluid to assure the change in direction of flow thereof for discharge into the curved portions.

16. In an elastic-fluid turbine, the combination of a row of wide blades, adapted to receive elastic fluid at one side and to discharge it at the tips and each of which comprises an outer curved portion and an inner substantially plane portion, and rib or partition means secured to the plane portions and suitably curved to assure the change in direction of elastic fluid received at one side of the blades for discharge at the tips.

17. In an elastic-fluid turbine, the combination of a row of blades adapted to receive elastic fluid at one side and to discharge it at the tips thereof, each blade comprising inner substantially plane portions and an outer curved portion and the mass thereof being so disposed that its center of gravity falls substantially midway thereof, and similarly placed guide ribs secured to opposite sides of each blade, the guide ribs of adjacent faces of adjacent blades cooperating to define partition or wall elements to secure a change in direction of elastic fluid received at one side of the blades for discharge at the tips.

18. In an elastic-fluid turbine, the combination of a row of blades adapted to receive elastic fluid at one side and to discharge it at the tips, each blade having an outer curved portion and inner substantially plane portion, and contacting curved guide ribs spot-welded to the inner substantially plane portions.

19. In an elastic-fluid turbine, the combination of a row of blades adapted to receive elastic fluid at one side and to discharge it at the tips, each blade comprising an outer curved portion to provide for the discharge of elastic fluid at a small angle and an inner substantially plane portion, and guide members of angle form spot-welded to the blades and contacting to define partition or wall elements adapted to secure a gradual change in direction of elastic fluid so that it may be discharged toward the blade tips.

20. In an elastic-fluid turbine, the combination of a row of blades adapted to receive elastic fluid at one side and to discharge it at the tips and contacting and curved guide ribs spot-welded to the blades to assure a gradual change in direction of elastic fluid so that the latter may be discharged toward the tips of the blades.

21. In an elastic-fluid turbine, the combination of a row of blades adapted to receive elastic fluid at one side and to discharge it at the tips thereof and curved angle members, each of which has one angle portion spot-welded to a blade and the other angle portion serving as a guide or partition member.

22. In an elastic-fluid turbine adapted to discharge elastic fluid transversely to the direction in which said fluid initially flows therein, the combination of a last row of blades adapted to receive elastic fluid at one side and to discharge it at the tips thereof and ribs carried by the blades to assure the gradual change in direction of elastic fluid passing therebetween.

23. In an elastic-fluid turbine adapted to discharge elastic fluid transversely to the direction in which said fluid initially flows therein, the combination of a last row of blades adapted to receive elastic fluid at the sides and to discharge it at the tips thereof and ribs carried by the blades and adapted to constitute partition or wall elements therebetween, whereby the direction of flow of elastic fluid is changed and the blades press each other.

24. In an elastic-fluid turbine, the combination of a row of blades adapted to receive elastic fluid at one side and to discharge it at the tips thereof and contacting ribs carried by the blades to assure a change in direction of flow of the elastic fluid and to reinforce the blades.

25. In an elastic-fluid turbine, the combination of a row of blades comprising inner radial portions and outer curved portions to discharge elastic fluid peripherally at small angles and contacting guide members carried by the blades for deflecting the elastic fluid and bracing the blade structure.

In testimony whereof, I have hereunto subscribed my name this 7th day of December 1921.

ALEXANDER T. KASLEY.