Oct. 9, 1923. 1,469,965

H. F. SCHMIDT

TURBINE

Filed July 6, 1921 5 Sheets-Sheet 1

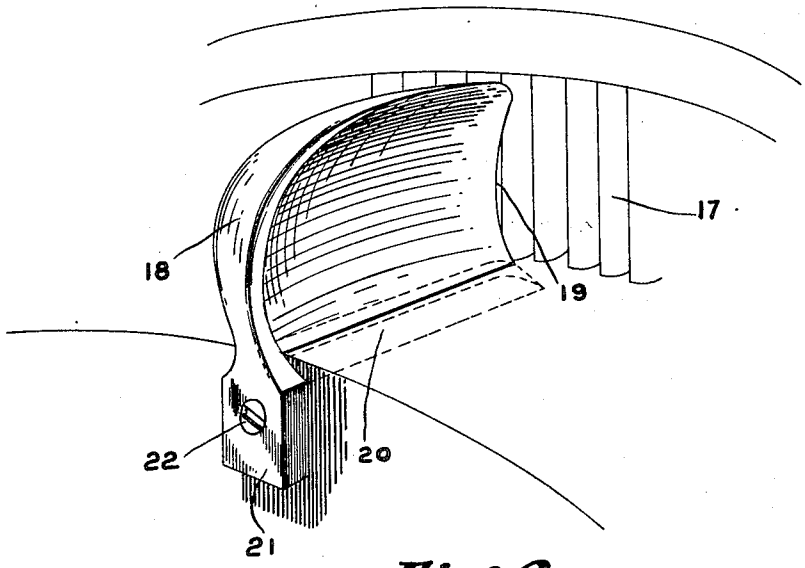


Fig. 2.

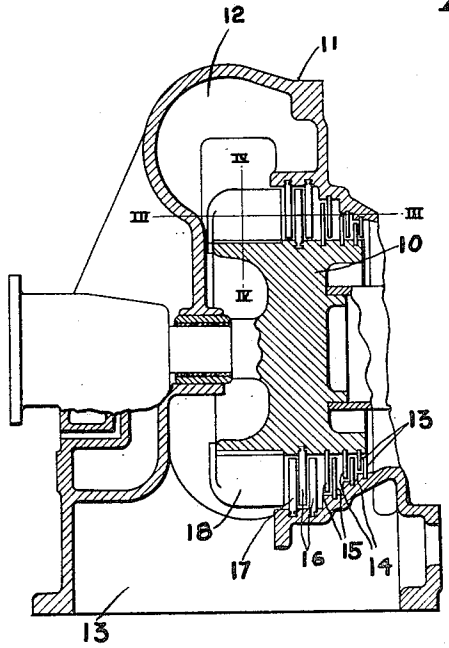


Fig. 1.



Fig. 3.



Fig. 4.

Henry F. Schmidt
INVENTOR

BY D. C. Davis
ATTORNEY

Oct. 9, 1923. 1,469,965

H. F. SCHMIDT

TURBINE

Filed July 6, 1921 5 Sheets-Sheet 2

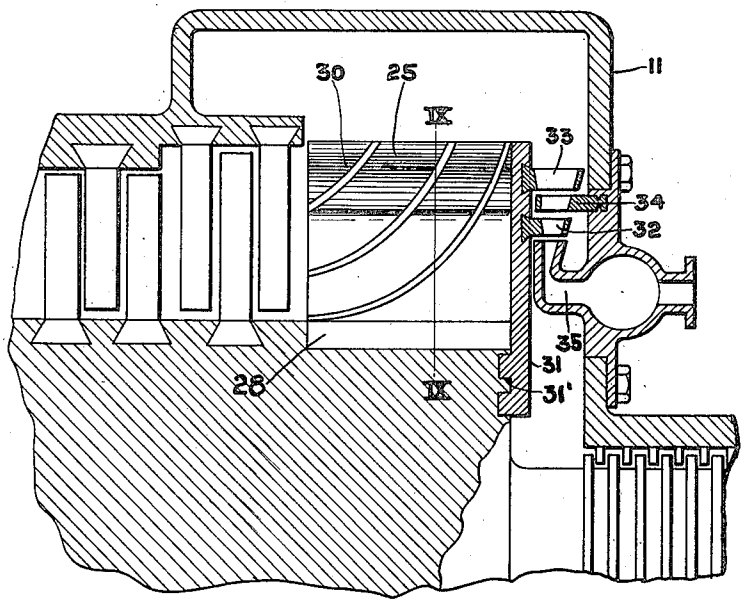


Fig. 5.

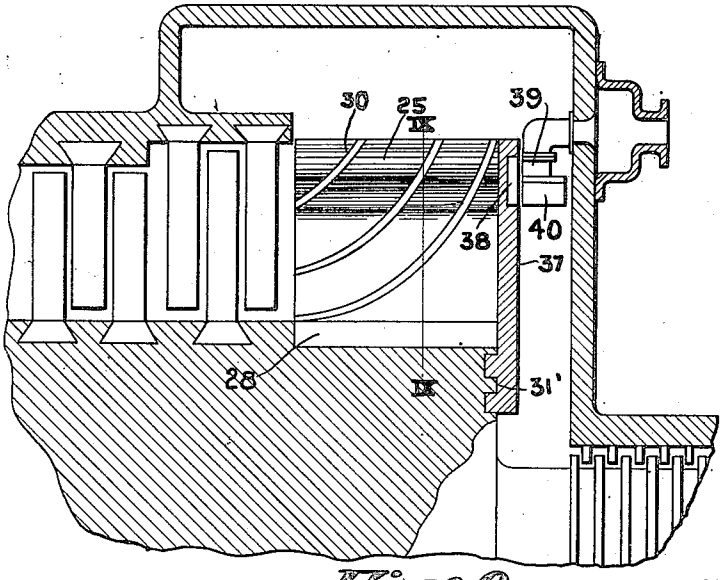


Fig. 6.

Henry F. Schmidt
INVENTOR

BY H. C. Davis.
ATTORNEY

Oct. 9, 1923. 1,469,965

H. F. SCHMIDT

TURBINE

Filed July 6, 1921 5 Sheets-Sheet 3

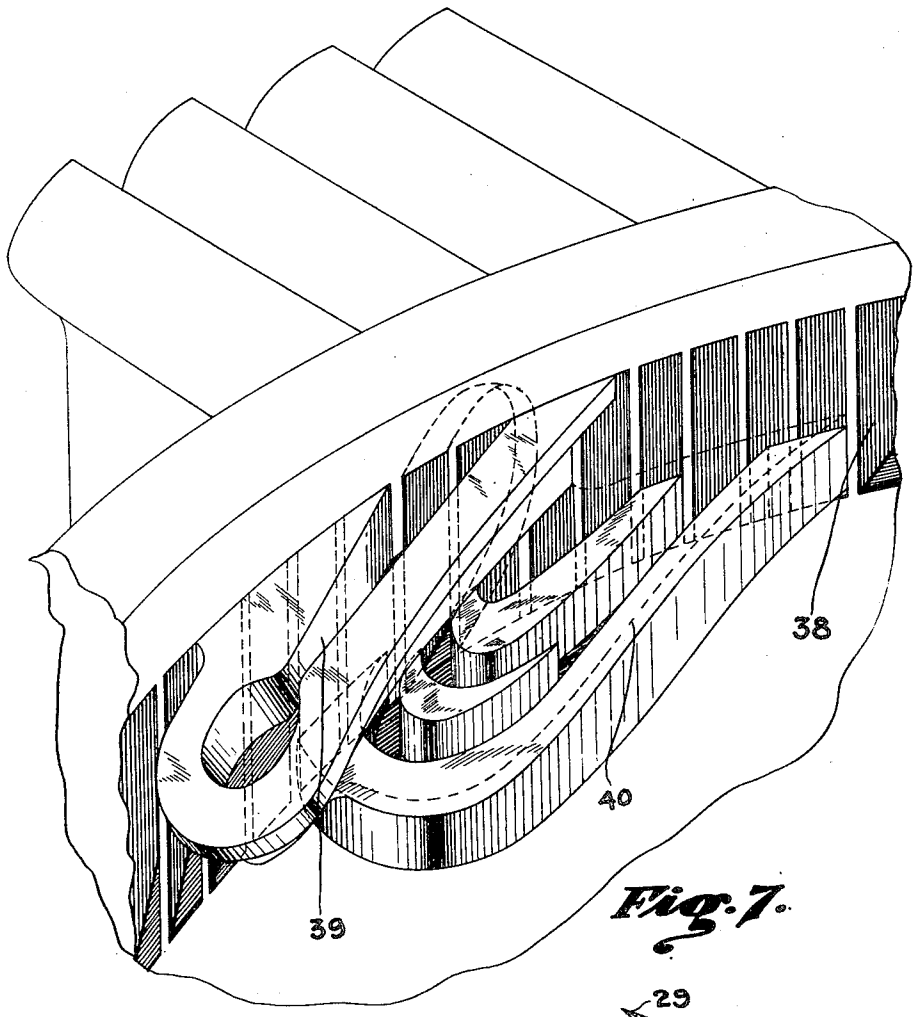


Fig. 7.

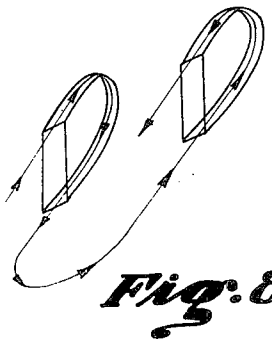


Fig. 8.

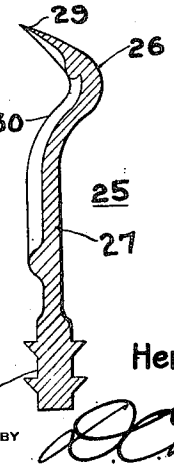


Fig. 9.

Henry F. Schmidt
INVENTOR

BY A. C. Davis
ATTORNEY

Oct. 9, 1923. **1,469,965**

H. F. SCHMIDT

TURBINE

Filed July 6, 1921 5 Sheets-Sheet 4

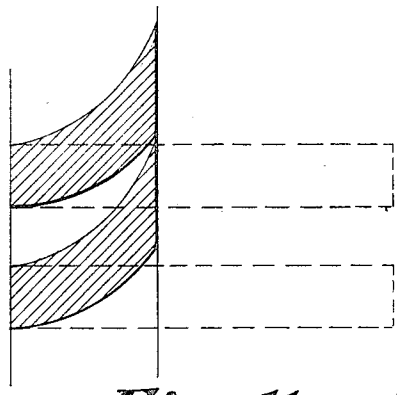


Fig. 11.

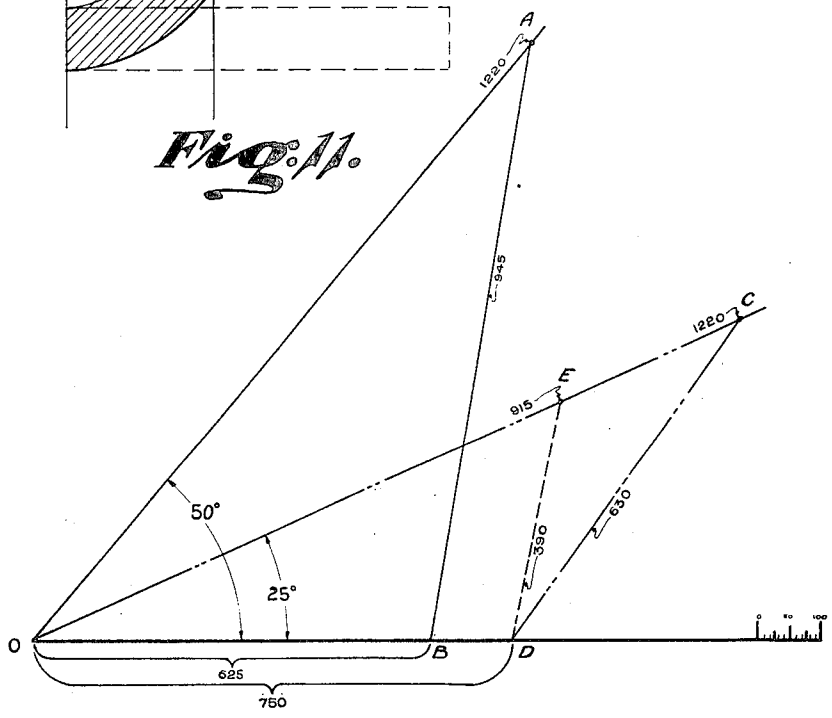


Fig. 10.

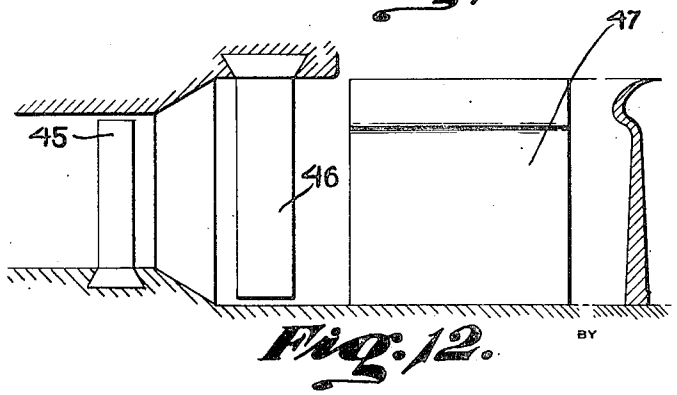


Fig. 12.

Henry F. Schmidt
INVENTOR

BY

D. C. Davis.
ATTORNEY

Oct. 9, 1923. 1,469,965

H. F. SCHMIDT

TURBINE

Filed July 6, 1921 5 Sheets-Sheet 5

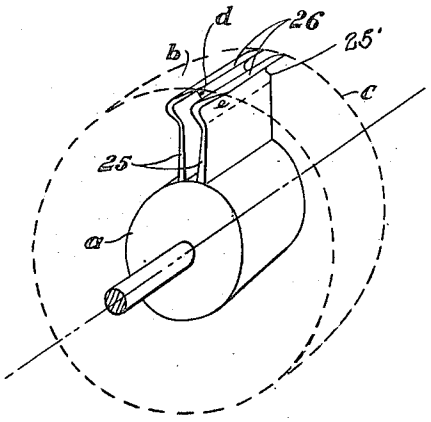


Fig. 13.

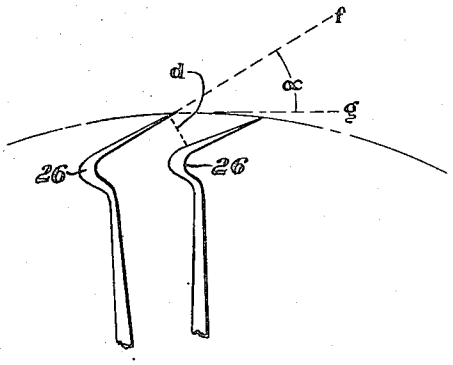


Fig. 14.

WITNESSES:

O. B. Wakefield

H. F. Schmidt
INVENTOR

BY D. C. Davis
ATTORNEY

Patented Oct. 9, 1923. 1,469,965

UNITED STATES PATENT OFFICE.

HENRY F. SCHMIDT, OF SWARTHMORE, PENNSYLVANIA, ASSIGNOR TO WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA.

TURBINE.

Application filed July 6, 1921. Serial No. 482,768.

To all whom it may concern:

Be it known that I, HENRY F. SCHMIDT, a citizen of the United States, and a resident of Swarthmore, 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.

My invention relates to blading for elastic-fluid turbines, more particularly for the low-pressure portions thereof, and it has for its object to provide apparatus of the character designated which shall have a small angle of discharge, adequate discharge area, and high effective blade speed, whereby high efficiency of the blading and the capacity thereof for handling large volumes of elastic fluid are obtained.

Another object of my invention is to provide a novel method of expanding elastic fluid by a rotating member so as to provide adequate discharge area and high efficiency of energy abstraction.

A further object of my invention is to provide a reversing or astern section which shall be compact and shall be provided with means to prevent the reversing or astern section from discharging into the ahead section or vice versa.

In the accompanying drawings, Fig. 1 is a sectional view of the low-pressure end of a turbine showing my improved blading; Fig. 2 is a detail perspective view showing one of my improved blades; Figs. 3 and 4 are sectional views taken along the lines III—III and IV—IV, respectively, of Fig. 1; Fig. 5 is a sectional view showing a modified form of the last-row blading together with a reversing section, Fig. 6 is a view similar to Fig. 5, but showing another form of reversing section; Figs. 7 and 8 are detail views of the reversing section used in Fig. 6; Fig. 9 is a sectional view taken along the line IX—IX of Figs. 5 and 6; Fig. 10 is a velocity diagram in which my new blading is compared with the old or existing type; and Figs. 11 to 14, inclusive, are diagrammatic views illustrating certain properties of my construction.

In the design and construction of elastic-fluid turbines, in accordance with existing practice, the last row of blades is in general a compromise, the height being limited by centrifugal stresses, and, with the maximum permissible blade height, it is necessary to provide large leaving angles for the blades in order to afford sufficient discharge area for the large volumes of low-pressure elastic fluid. Accordingly, I have provided a novel type of blading suitable for the last row and which is capable of passing large volumes of low-pressure, elastic fluid and, at the same time, of preserving small discharge angles, necessary for high blade efficiency.

Also, the construction of large single-unit turbines has disclosed the difficulty of excessive blade speeds due to the necessarily large diameter at the low-pressure end and to the height of blades necessary to provide sufficient exit area so that the steam may not be discharged with too great residual energy. The reissue patent to Baumann No. 15,092, reissued April 26, 1921, discloses a low-pressure turbine section which is adapted to afford large discharge area without exceeding safe blade speeds. My improved blading attains this object in a different and simpler way.

More specifically, my moving blades are made relatively wide, having a width comparable to the height, and are so arranged as to receive elastic fluid axially and to discharge it peripherally or peripherally and laterally. With blading of this type, for a given discharge angle, ample discharge area is provided merely by choosing a suitable blade width since the discharge area is equal to the number of blades times the throat width of the nozzle passages between the blades times the effective width or length of a nozzle passage, and the latter factor is dependent upon the blade width. The peripheral discharge is advantageous as the reactive force of the elastic fluid is applied to the blades where the effective speed is higher than the mean speed with ordinary axial-flow blading, thereby resulting in the conversion of a greater portion of the kinetic energy into useful work.

Referring now to the drawings for a more detailed explanation of my invention, I show a turbine rotor 10, journaled in a suitable casing or cylinder 11, the casing being provided with an exhaust chamber 12 communicating with an exhaust outlet 13. Motive or elastic fluid, such as steam, is received in the usual way, is expanded in the stages carried by the rotor and the casing, and is discharged into the exhaust chamber, from

which it flows through the exhaust outlet 13 to a suitable condenser, not shown, or, the form of blading shown may be used in connection with a turbine discharging to the atmosphere, although its greatest field of usefulness is in connection with condensing turbines where large volumes of low-pressure elastic fluid must be handled.

In Fig. 1, I show a plurality of successively arranged stages 13, 14, 15, and 16, the stage 13 being adapted to receive elastic fluid which has undergone expansion in higher pressure stages, not shown, and the stage 16 being adapted to discharge into the last, low-pressure stage, comprising a stationary row of blades 17, carried by the casing, and a row of relatively wide blades 18, carried by the rotor. While I have shown the stages 13, 14, 15, and 16 of the reaction type, it will be obvious to those skilled in the art that stages of the impulse or any suitable type might be used. Ordinarily, the axial flow reaction stages would be used until the safe limit of centrifugal stress for the last row of moving blades thereof is reached, with discharge angles small enough to give good blade efficiency, and then these would be followed by my novel row of wide moving blades which is capable of efficiently handling large volumes of elastic fluid.

The last-row, moving blades 18 are adapted to receive elastic fluid axially and to discharge it peripherally or peripherally and laterally. It will be apparent that the peripheral discharge permits of increasing the discharge area, while preserving a small discharge angle, as any suitable width of blade may be selected. The blades may be shaped in any suitable way to secure the discharge of elastic fluid in the manner stated to act reactively on the blades.

In Figs 1–4, inclusive, I show blades 18 curved in radial, axial, and combined radial and axial directions, thereby resulting in cup-like or dish-like blades adapted to receive elastic fluid flowing in an axial direction between the substantially radial inlet edges 19. The elastic fluid undergoes expansion between the blades and is discharged both peripherally and laterally at high velocity.

It will be obvious that the average distance of application of the reaction of the elastic fluid to the blades, is nearer the tips than in the conventional type. In the axial-flow type of blade, the mean effective blade speed is taken as the speed of the mid-height. In my construction, due to the peripheral discharge, the average of all points of application is nearer the tip of each blade and hence the effective blade speed is higher and a larger portion of the kinetic energy of the elastic fluid may be converted into useful work. As is hereinafter pointed out, if the elastic fluid is discharged wholly peripherally, the effective blade speed is, of course, the tip speed.

As the blades may be made of any desired width to secure an adequate discharge area, the leaving edges may be made to discharge elastic fluid at a small angle, thereby increasing the blade efficiency.

The blades 18 may be secured to the rotor 10 in any suitable manner, for example, by dovetail connections 20; and, if desired, overhanging tongues 21 for the blades and suitable screws 22 for securing the tongues to the rotor may be provided.

In Figs. 5 and 6, I show rows of relatively wide blades 25 of a modified form in which the elastic fluid is discharged peripherally, thereby resulting in the effective blade speed being that of the tips. Each blade preferably comprises an outer hook-like or trough portion 26 and an inner radial portion 27, adapted to be secured to the rotor 10 in any suitable manner, for example by dovetail connections 28. A section of the blade is shown in Fig. 9. Preferably, each blade is so designed that its center of gravity falls mid-way of the thickness of the radial portion as to avoid bending moments due to centrifugal force, which would occur if the center of gravity should fall to one side; and the outer portions 29 of the trough or hook-like portions may define elastic-fluid, diverging, expanding passages, to secure a greater range of expansion, all as set forth in the co-pending application of Alexander T. Kasley, Ser. No. 486,517, filed July 21, 1921, continued as Ser. No. 521,872, filed December 12, 1921, and assigned to the Westinghouse Electric and Manufacturing Company.

The blades 25 are preferably provided with curved ribs 30 which serve to strengthen the latter as well as to assist in changing the direction of flow of the elastic fluid from an axial to a radial direction.

The outer edges of the blades are blocked by suitable blocking plate members, 31 in Fig. 5 and 37 in Fig. 6, which assure the peripheral discharge of elastic fluid. The blocking plate members are secured to the rotors in any suitable manner, for example, by tongue-and-groove connections 31′; and are preferably secured to the outer edges of the blades. In operation, the blades 25 and the blocking plates 31 and 37 reinforce and assist in supporting each other, this being particularly true when a blocking plate carries reversing blades on one side, as hereinafter described.

Reversing sections or stages of the radial-flow type may be associated with the blocking plates 31 and 37, the plates serving as deflectors to keep the reversing section from discharging into the ahead section or vice versa, thereby avoiding energy losses which

would otherwise occur due to this cause. Also, a reversing section or stage of this type may be incorporated with an ahead section to produce a very compact and highly efficient marine turbine.

In Fig. 5, I show a reversing stage or section of the radial-flow, two-row, multi-velocity type which includes concentric rows of blades of energy abstracting elements 32 and 33 carried by the blocking plate member 31, aforesaid, and between which is located the reversing segment of stationary blades 34. A suitable nozzle 35 is carried by the casing 11 and discharges motive fluid at high velocity into the first row of moving blades or energy-abstracting elements 32, the energy of the motive fluid being taken out in two steps, namely, in the row of blades or energy-abstracting elements 32 and in the row of blades or energy-abstracting elements 33. It will be obvious that any centrifugal moment, due to the unbalanced masses of the blades or energy-abstracting elements 32 and 33, will be withstood by the relatively wide blades 25 acting as sustaining struts for the other side of the blocking plate 31.

Referring to Figs. 6, 7, and 8, the construction is the same as that shown in Fig. 5, except for a modified form of reversing element. In Fig. 6, I show a reversing element comprising a single series of inclined impulse buckets or energy-abstracting elements 38, arranged on one side of the blocking plate 37, with which cooperate the expanding nozzle 39 and the reversing chamber 40, preferably carried by the upper half of the turbine casing 11, motive fluid being expanded in the nozzle and discharged therefrom at high velocity to act impulsively upon the buckets or energy-abstracting elements 38, and, after passing through the latter and having its direction changed, the motive fluid enters the reversing chamber 40, where its direction is again changed, for impingement against the buckets or energy-abstracting elements a second time. In this way, the velocity energy of the motive fluid discharged from the nozzles 39 is taken out in two steps. The passage of motive fluid will be readily understood upon reference to Fig. 8, wherein the arrows indicate the direction of flow of motive fluid from a nozzle to a bucket or energy-abstracting element, from the latter to the reversing chamber, and from the reversing chamber to another bucket or energy-abstracting element.

As the reversing section or stage shown in Figs. 6, 7, and 8 does not contain any interfitting elements carried by the rotor and cylinder or stator, it will be apparent that the upper portion of the latter may be readily removed without removing any of the reversing section elements.

The feature of providing adequate discharge area will be obvious from a consideration of diagrammatic Fig. 13 which shows in perspective a portion of a rotor provided with a row of wide blades 25 having inlet edges 25′. Only two of the blades are shown, but it is to be understood that a circumferential series is employed in the bounding circles indicated at *b* and *c*. The blades as shown are of the type which are adapted to receive motive fluid between the inlet edges 25′, to change the direction of flow thereof between the blades, and to discharge the same radially from curved energy-abstracting portions 26. Assuming that the throat width of an expansion passage defined between the outer curved portions 26 of a pair of adjacent blades 25 is *d*, then each throat area would be equal to *d* x *e*, where *e* is the blade width.

If the wide blades discharge elastic fluid in an axial direction as well as radially, then to the extent that axial discharge is permitted just to that extent more discharge area is provided in addition to the radial discharge area. Therefore, with blading of the general form indicated in Figs. 1 to 4, inclusive, owing to the additional axial discharge area, they may be made relatively narrower than the form of blading indicated in Fig. 13 with the preservation of the same discharge area. It is to be understood, therefore, that the provision of adequate discharge area with any of the forms of blading coming within the purview of my invention involves merely the selection of such a width of blade which will give the necessary total discharge area.

Owing to the fact that considerable latitude in the choice of a width of blade is permissible in accordance with my construction, the blades may be made sufficiently wide to provide small discharge angles and at the same time adequate discharge area. The feature of relatively small discharge angles will be evident from a consideration of Fig. 14 which shows in detail two adjacent curved energy-abstracting blade portions 26 which are adapted to discharge elastic fluid peripherally and at an angle. The angle referred to is the angle which the tangent to the outer edge of the concave blade portion makes with the tangent to the circle of the outer blade edge at the discharge tips of the blades. This angle is indicated by the angle α in Fig. 14, included between the dotted line *f* representing a continuation of the inner discharge surface of one of the portions 26 and the line *g* which is the tangent to the blade tip circle at the blade tip referred to.

From the foregoing, the operation of apparatus made in accordance with my invention will be readily understood. Elastic fluid, such as steam, is expanded and flows

axially in all stages except the last, where its direction is changed, being received thereby flowing in an axial direction and expanding and discharging it peripherally or peripherally and laterally.

The feature of peripheral discharge, as already pointed out, permits of the provision of adequate discharge area, of smaller discharge angles, and of greater effective blade speeds, these factors all contributing to increase materially the efficiency of the last row of moving blades and consequently the over-all efficiency of the turbine. This will be evident from a consideration of the diagram of Fig. 10, in which a conventional last-row blade having an outlet angle of, for example, 50° is compared, from the standpoint of blade efficiency, with my improved blade having an outlet angle of, for example, 25°. Let AO represent the velocity of elastic fluid leaving a last-row of 50° blades, which, for purposes of illustration, is assumed to be the critical velocity. 1220 feet per second, at one-half pound per square inch absolute pressure, and assume that the mean or effective blade speed OB is 625 feet per second. Solving the triangle AOB, the ineffective or residual velocity AB is found to be 945 feet per second. From the well-known formula, the efficiency of the 50° blades is found to be:—

$$\text{Efficiency} = \frac{V_1^2 - V_2^2}{V_1^2}$$

$$\frac{AO^2 - AB^2}{\overline{AO}^2} = \frac{1220^2 - 945^2}{1220^2} = 40\%$$

With my new form of blade, the effective blade speed is higher for the reason that the kinetic energy is effective resultantly further out than mid-height. Therefore, with the same r. p. m., producing a mean effective blade speed of 625 feet per second, it is possible to obtain a higher effective blade speed, say 750 feet per second, resulting in a greater portion of the kinetic energy being converted into useful work. With elastic fluid being discharged at 1220 feet per second, which would correspond to a turbine of 33% greater power, the efficiency of my new blade under the conditions assumed would be:—

$$\frac{OC^2 - CD^2}{OC^2} = \frac{1220^2 - 630^2}{1220^2} = 73\%$$

Due to the higher efficiency of my last-row, low-pressure blading, it is possible to utilize lower steam velocities in apparatus of the same power capacity as the old. For example, assume a turbine with my form of blading having the same capacity as the turbine having the 50° blades referred to, then since my blading has a greater discharge area for a given diameter, it is not necessary to utilize the critical velocity at discharge; but because of the gain of 33% in area, the velocity may be reduced to 915 feet per second, in which case the efficiency of the last-row would be:—

$$\frac{OE^2 - ED^2}{OE^2} = \frac{915^2 - 390^2}{915^2} = 82\%$$

From a consideration of the above, it will be seen that, in the example assumed, my blading is nearly 100% more efficient than the blading of the old type, which increase of efficiency is due to the possibility of using a smaller discharge angle, adequate discharge area being provided, and to the higher effective blade speed.

To show the effect of my blading on the performance of the complete turbine, let it be assumed that two turbines of the same capacity are operated under steam conditions, such that a total of 400 B. t. u. are available, and that the turbines are both alike except in the last row of blades. It may be assumed then that the turbine with 50° blades will have an overall efficiency of 80% or would convert 320 B. t. u. into useful work. Now however, the critical velocity corresponds to 30 B. t. u. which, in the turbine with 50° blades, is handled by blades having an efficiency of 40%, that is 12 B. t. u. are actually converted into work, whereas in my turbine these same 30 B. t. u. are handled at an efficiency of something over 80%, or approximately 24 B. t. u. are converted into useful work. Therefore, in my turbine, 320 plus 12, or 332 B. t. u. are converted into useful work, or my turbine is

$$\frac{12}{320} = 3.75\%$$

more efficient than the old turbine.

It is to be understood that the diagram and the velocity values noted thereon, shown in Fig. 10, are used for illustrative purposes only and not in a limiting sense.

It is old, in connection with low pressure blading, to taper the blades by increasing the thickness circumferentially in order to provide sufficient strength for an increase in height necessary to pass large volumes of low-pressure elastic fluid; however, it will be obvious that such tapering is accompanied by a restriction of the outlet or discharge area. On the other hand, with my new type of blading, due to the fact that elastic fluid is discharged at the tips, practically involving as a characteristic the provision of a root connection approximately equal in length to the discharge edges, the blades may be tapered without in any way affecting the outlet or discharge area. This will be evident from a consideration of Figs. 11 and 12. In Figure 11, I show hatched outlines or sec-

tions near the roots of blading of the old tapered type and dash line outlines of sections of my improved tapered blading and having the same taper. It will be seen that the blading of the old type is shown in contact at the leaving or outlet side, whereas my new blade having the same inlet pitch and the same degree of taper is uniformly spaced from side to side, due to the fact that the inner portions of my blades are arranged substantially parallel to the axis of the turbine. In view of the fact that, with my new form of blading, the outlet area is not affected by tapering and to the further fact that tapering may be carried to a greater extent, it is apparent that higher blading may be constructed according to my type than is possible with the old type. Therefore, with tapered blading of the old type, the height is limited by the outlet area, it being obvious that no advantage accrues in further increasing the height of the blades after they begin to contact at the outlet edges adjacent to the roots; whereas, with blading of my type, the outlet area in no way being affected by tapering, the height is limited only by practical structural limitations as to tapering.

Fig. 12 shows diagrammatically the possibility of increasing the height of my new form of blade over that possible with the old form, as mentioned in connection with Fig. 11. The moving blades 45 may be made as high as possible, with the preservation of good efficiency, and are adapted to discharge elastic fluid for passage through the guide blades 46, and as the latter are carried by the stator, they may, of course, be made much longer than the blades 45. As it is possible to make my new form of blade taller than the old form, the row of blades 47 may be made of an appropriate height to receive the elastic fluid discharged from the guide blades 46.

It will, therefore, be seen, from a consideration of Figs. 11 and 12, that my new form of blading may be made higher or taller than the old type and may be tapered without affecting the discharge area.

Another advantage of my blading is the possibility of building larger turbine units. As a turbine of the standard type is made larger, a limit is reached for which it is capable of discharging low-pressure motive fluid with good efficiency. In other words, as already stated, centrifugal force imposes a limit on the blade height, and therefore, blades have to be provided with large outlet angles to accommodate the large volumes of low-pressure motive fluid. It will, therefore, be seen that the discharge area provided by the last row of blades is limited in the old type and is always less than the area swept by the inlet edges, and this factor serves to limit the practical and economical size of a turbine unit. On the other hand, with my new form of blade, due to the peripheral discharge, the blade width may be made such that the discharge area is equal to the area swept by the inlet edges of the blades; and, therefore, since the discharge area is not a limiting factor to the same extent, as in existing practice, it is possible to build units of larger size than heretofore.

It is to be understood that my novel blading may be modified or applied wherever its use may be desirable. For example the blading may be applied to the low-pressure ends of a double-flow turbine. Also, blading made in accordance with the principles of my invention may be used in a radial-flow turbine, for example the Ljungstrom type, it being only necessary to have the elastic fluid enter between the blades at the edges thereof nearest the turbine axis and to discharge outwardly and laterally as disclosed in the application of Herbert T. Herr Ser. No. 504,534, filed September 30, 1921.

It is obvious that one of the principal features of my invention is the provision of adequate discharge area which in turn is dependent upon the ability to provide discharge edges of any suitable extent, while, at the same time, preserving high blade efficiency. It is charateristic of my novel design of blading that an extremity of the outlet or discharge edge is adjacent to or adjoins one extremity of the inlet edge.

From the foregoing, it will be seen that I have devised a new form of last-row blading which is capable of passing large volumes of low-pressure motive fluid with high blade efficiency, and at the same time, of utilizing a high effective blade speed; and therefore, I am enabled to produce a more efficient turbine, or one, which, when compared with a turbine of like power of the old type, is capable of discharging at a lower velocity. Also, I have provided a reversing stage or section which coacts with my new form of last-row blades to produce a compact turbine unit and one in which flow from the reversing section to the ahead section or vice versa is effectively prevented.

While I have shown my invention in but three 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 specifically set forth in the appended claims.

What I claim is:—

1. An elastic-fluid turbine comprising a plurality of energy-abstracting stages through which the elastic fluid flows in the

same general direction and a stage including a row of moving blades each having a continuous surface and which are adapted to receive elastic fluid flowing in the same general direction from the preceding stages and to expand and to discharge the same in a substantially different direction.

2. An elastic-fluid turbine comprising a plurality of energy-abstracting stages through which the elastic fluid flows in the same general direction and a last, low-pressure stage including a row of moving blades each having a continuous surface and which are adapted to receive elastic fluid flowing in the same general direction from the preceding stages and to expand and to discharge the same in a substantially different direction.

3. An elastic-fluid turbine comprising a plurality of energy-abstracting stages through which the elastic fluid flows in the same general direction and a stage including a row of moving blades each having a continuous surface and which are adapted to receive elastic fluid flowing in the same general direction from the preceding stages and to expand and to discharge the same substantially normally to said direction.

4. An elastic-fluid turbine comprising a plurality of axial-flow, energy-abstracting stages and a stage including a row of moving blades each having a continuous surface and which are adapted to receive elastic fluid flowing in an axial direction and to expand and to discharge said fluid in a different direction.

5. In an elastic-fluid turbine, the combination of a plurality of axial-flow stages and a last stage having a row of moving blades which receive elastic fluid flowing in an axial direction and which are curved to provide for the discharge of elastic fluid peripherally at small angles.

6. In a turbine, the combination of a plurality of stages of the axial-flow type and a low-pressure stage adapted to receive elastic fluid from the axial-flow stages and having a row of moving blades curved to provide small discharge angles peripherally and laterally.

7. In a turbine, the combination of a plurality of stages of the axial-flow type and a low-pressure stage for receiving elastic fluid discharged from the axial-flow stages and having a moving row of blades which receive elastic fluid flowing in an axial direction and which are curved to provide for the discharge of elastic fluid peripherally at small angles and which are of sufficient width to provide a suitable discharge area.

8. In a turbine, the combination of a plurality of axial-flow stages followed by a low-pressure stage including a row of blades each having a continuous surface and which are adapted to receive motive fluid axially and to expand and discharge the same radially and axially.

9. An elastic-fluid turbine stage comprising a row of moving blades each having a continuous surface and which are relatively wide compared to their height, which have their tip and root edges arranged substantially parallel, and which are adapted to receive elastic fluid laterally and to expand and discharge the same peripherally.

10. In an elastic-fluid turbine, a last row of moving blades each having a continuous surface and having their roots arranged substantially parallel to the turbine axis and adapted to expand elastic fluid and to discharge it laterally and peripherally.

11. In an elastic-fluid turbine, a last stage including a row of moving blades each having a continuous surface which blades are relatively wide compared to their height, have their roots arranged substantially parallel to the turbine axis, and are adapted to receive elastic fluid laterally and to discharge the same peripherally.

12. In an elastic-fluid turbine, a last stage including a row of moving blades having their roots arranged substantially parallel to the turbine axis and being curved both radially and longitudinally to provide for the radial and longitudinal discharge of elastic fluid.

13. In an elastic-fluid turbine, a low-pressure stage including a row of moving blades which receive elastic fluid laterally and which are curved to provide peripheral energy-abstracting portions for the discharge of elastic fluid at a small tangential angle.

14. In an elastic-fluid turbine, a low-pressure stage arranged to receive elastic fluid flowing in an axial direction and including moving blades which are relatively wide compared to their height and which are curved to provide energy-abstracting portions for the discharge of elastic fluid peripherally at small angles.

15. In an elastic-fluid turbine, a row of peripherally-discharging blades, which receive elastic fluid laterally, which are curved to provide small discharge angles, and which are sufficiently wide to provide a suitable discharge area.

16. In an elastic-fluid turbine of the axial flow type, a low-pressure row of moving blades having curved portions adapted to discharge elastic fluid axially and radially at small angles.

17. In an elastic-fluid turbine, a row of moving blades each having a continuous surface, which blades are adapted to receive elastic fluid at one side and to discharge the same laterally and peripherally and having such a width that a suitable discharge area may be provided.

18. In an elastic-fluid turbine, a row of

moving blades adapted to receive elastic fluid at one side and having curved portions for discharging the same peripherally and having such a width that the discharge area may be made at least as great as the area swept by the inlet edges of the blades.

19. In an elastic-fluid turbine, a row of moving blades each having a continuous surface, said blades being arranged to receive elastic fluid axially and being provided with energy-abstracting portions at the tips, whereby the effective blade speed is the tip speed.

20. In an elastic-fluid turbine of the axial-flow type, a last row of moving blades adapted to receive elastic fluid axially and being curved radially and axially to provide for the angular discharge of elastic fluid radially and axially.

21. In an elastic-fluid turbine, a row of blades having elastic-fluid discharge and energy-abstracting portions at the tips, root portions opposite to the tips and substantially of the same width as the latter, and lateral edges to receive elastic fluid.

22. In an elastic-fluid turbine, a row of tapering blades having elastic-fluid discharge and energy-abstracting portions at the tips, root portions opposite to the tips and substantially of the same width as the latter, and inlet edges for elastic fluid disposed transversely of the tips and of the root portions.

23. A blade for an elastic-fluid turbine having substantially parallel elastic fluid discharge tip and root edges and an inlet edge disposed transversely of the first-mentioned edges.

24. A blade for an elastic-fluid turbine having its inlet edge disposed normally of its root and being curved to provide a tip discharge edge.

25. A blade for an elastic-fluid turbine having its inlet edge normal to its root and being curved to provide peripheral and lateral discharge edges.

26. A blade for an elastic-fluid turbine curved to provide peripheral and lateral discharge edges arranged to discharge elastic fluid at small angles.

27. A blade for an elastic-fluid turbine having inlet and discharge edges disposed transversely to each other, said inlet and discharge edges having adjacent extremities.

28. A blade for an elastic-fluid turbine having a root portion and a discharge edge opposite to the root portion which discharge edge has an extremity adjacent to the inlet edge.

29. A turbine blade adapted to receive motive fluid at one side and being curved radially and axially to provide radial and axial discharge and energy-abstracting portions.

30. A turbine blade which is substantially rectangular in outline adapted to receive motive fluid at one side and being curved in the directions of its height and of its width to provide height-wise and width-wise discharge and energy-abstracting portions.

31. A turbine blade adapted to receive elastic fluid axially and being curved to provide for the discharge thereof at a small angle and being provided with one or more ribs curved from an axial toward a radial direction to guide the elastic fluid and to strengthen the blade.

32. A turbine blade having a width which approximates its height and being provided with a lateral inlet edge and being curved to provide a peripheral portion arranged to discharge elastic fluid at a small angle.

33. In an elastic-fluid turbine, a row of blades tapered from the roots toward the tips, having inlet edges at one side and being curved to provide energy-abstracting portions at the tips.

34. In a multi-stage elastic-fluid turbine, a last row of moving blades adapted to receive elastic fluid axially and to discharge it peripherally, and having curved ribs to strengthen the blades and to assist in changing the direction of the elastic fluid from an axial to a radial direction.

35. In an axial-flow turbine, the combination of a last low-pressure stage including a moving row of blades which are adapted to receive elastic fluid flowing in an axial direction and to discharge it peripherally and a reversing radial-flow stage arranged at the outer edge of the moving blades of said low-pressure stage.

36. In a turbine having a plurality of axial-flow stages, the combination of a low-pressure stage having a row of moving blades adapted to receive axially flowing elastic fluid and to discharge it peripherally, said moving blades being curved to provide small discharge angles, means for blocking the outer edges of the moving blades, and a reversing radial-flow stage having the moving energy-abstracting elements thereof carried by said blocking means.

37. In a multi-stage turbine, the combination of a low-pressure stage having moving blade structure adapted to receive elastic fluid flowing in an axial direction and a reversing radial-flow stage having the moving blades thereof supported by said blade structure.

38. In a turbine having a plurality of stages, the combination of a last low-pressure stage including a row of relatively wide moving blades receiving motive fluid axially and discharging it peripherally, blocking means for the outer edges of the wide blades, and reversing energy-abstracting elements carried by the blocking means.

39. In a turbine having a plurality of stages, the combination of a last low-pres-

sure stage including a row of relatively wide moving blades, adapted to receive motive fluid axially and to discharge it peripherally, reinforcing means for the outer edges of the wide blades, and reversing energy-abstracting elements carried by the reinforcing means.

40. In a turbine having a plurality of stages, the combination of a last low-pressure stage including a row of relatively wide moving blades adapted to receive motive fluid axially and to discharge it peripherally, blocking means for the outer edges of the wide blades, and radial-flow reversing energy-abstracting elements carried by the blocking means.

41. In a turbine having a plurality of stages, the combination of a last low-pressure stage including a row of relatively wide moving blades adapted to receive motive fluid axially and to discharge it peripherally, blocking means for the outer edge of the wide blades, and radial-flow reversing energy-abstracting elements carried by the blocking means, said wide blades serving to resist deflection of blocking means due to centrifugal effects.

42. In a elastic-fluid turbine having a casing, a rotor, and a plurality of stages carried thereby, the combination of a last stage adapted to receive fluid axially and to discharge it peripherally, means for blocking the outer edges of the moving blades, and a reversing element comprising lateral buckets carried by the blocking means and a nozzle and a reversing chamber carried by the casing and cooperating with the buckets.

43. In an elastic-fluid turbine having a casing, a rotor, and a plurality of stages carried thereby, the combination of a last stage adapted to receive elastic fluid axially and to discharge it peripherally comprising relatively wide moving blades, means for blocking the outer edges of the moving blades, lateral buckets carried by the blocking means, and a nozzle and reversing chamber carried by the casing and cooperating with the buckets.

44. In an elastic-fluid turbine, the combination of an ahead section, a reversing section, and a plate member to prevent discharge from one section into the other, the energy-abstracting elements of the reversing section being carried by the plate member.

45. In an elastic-fluid turbine, the combination of an ahead section, a radial-flow reversing section, a plate member between the sections to prevent flow from one section into the other, and supporting the energy-abstracting elements of the reversing section.

46. In an elastic-fluid turbine, the combination of an ahead section adapted to expand elastic fluid axially and finally radially, a radial-flow reversing section comprising moving buckets and a cooperating stationary nozzle and reversing chamber, a plate member between the sections to prevent flow from one into the other and carrying the buckets, and a cylinder upper portion or cover carrying the nozzle and reversing chamber, whereby the upper portion or cover, with the nozzle and reversing chamber, may be readily removed.

In testimony whereof, I have hereunto subscribed my name this 30th day of June, 1921.

HENRY F. SCHMIDT.