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F. LJUNGSTRÖM

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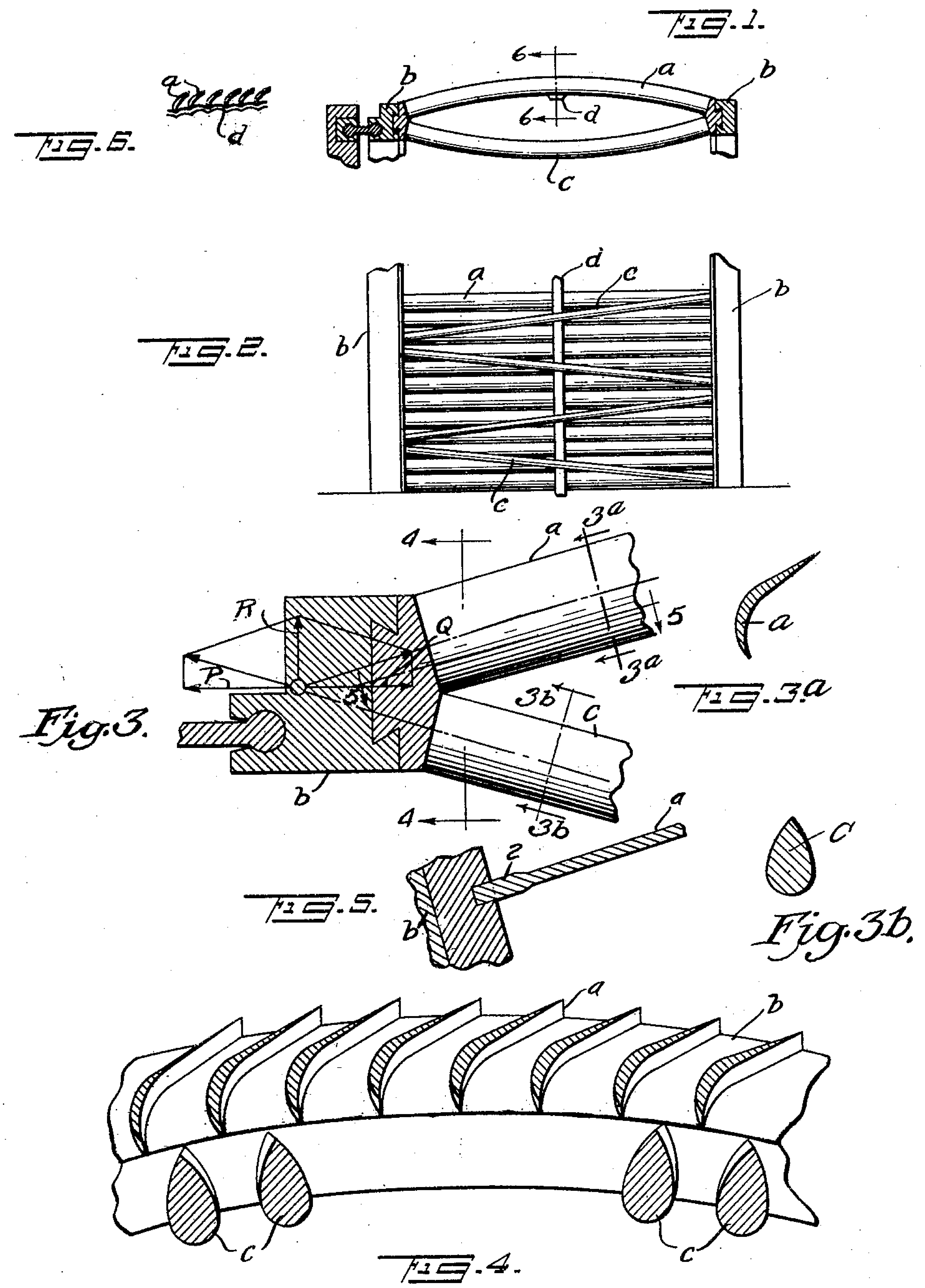
VANE RIM FOR TURBINES

Filed Aug. 16, 1929

2 Sheets-Sheet 1



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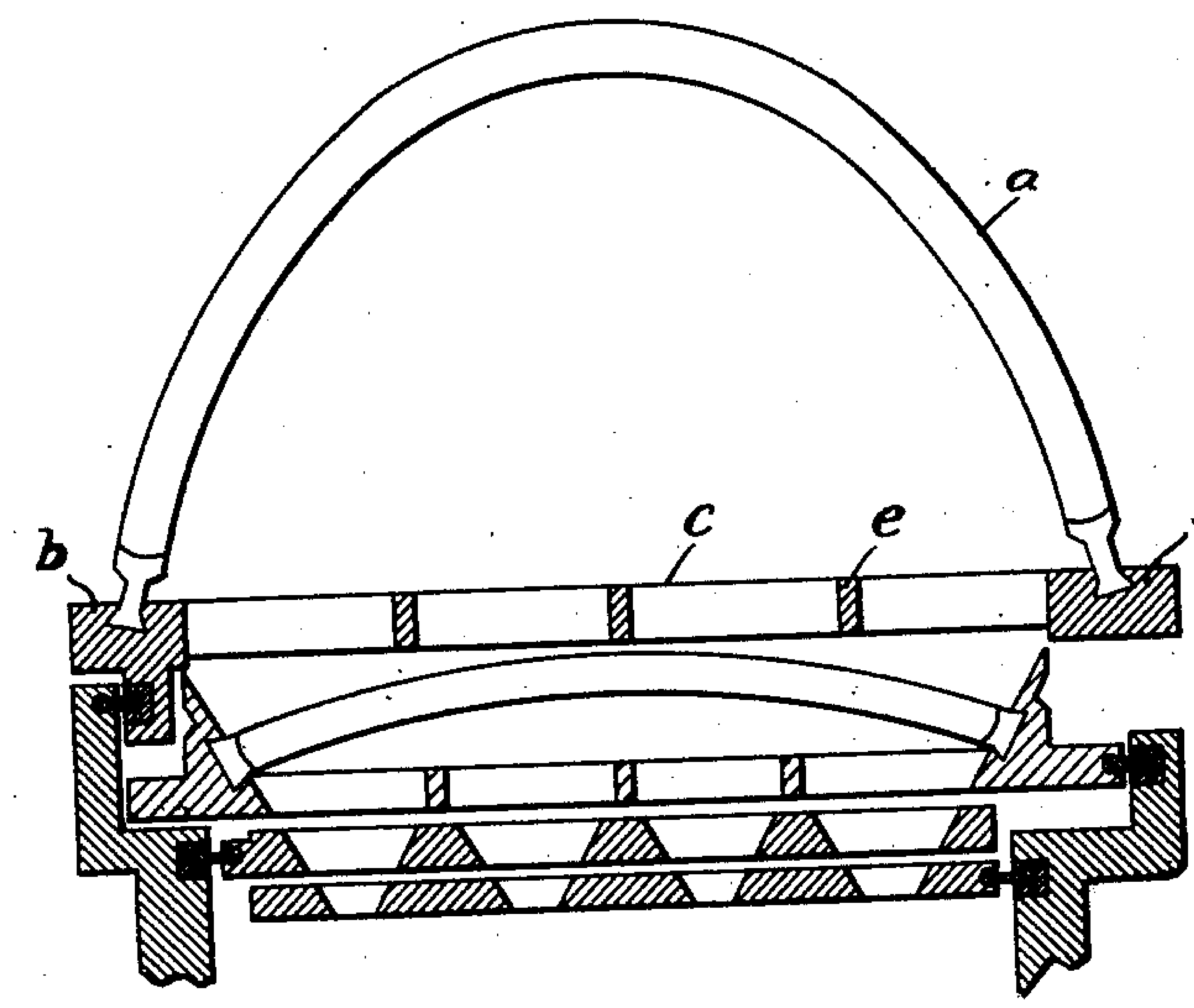

Fig. 7.

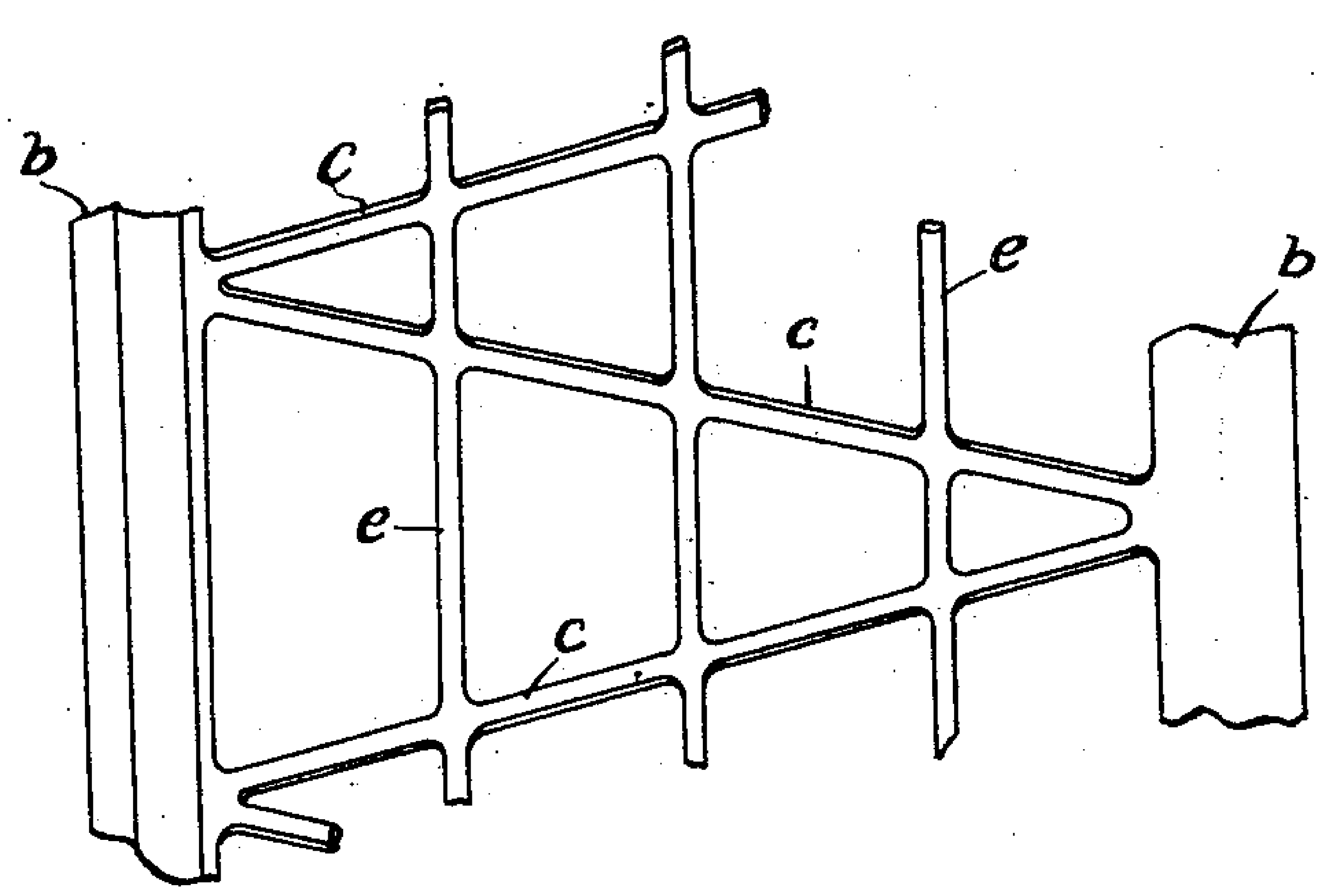

Fig. 8.

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UNITED STATES PATENT OFFICE

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VANE RIM FOR TURBINES

Application filed August 16, 1929, Serial No. 386,241, and in Sweden August 18, 1928.

In turbines, especially steam turbines of the kind in which the driving medium passes through the turbine in radial direction, which type of turbine is generally known under the denomination "Ljungström turbines", the maximum output of the turbine is limited by the cross-sectional area of the steam passage between the blades of the outermost rotor of the turbine. The magnitude of said area depends on how long the blades can be made, the length, in turn, being determined by the capacity of the blades to take up stresses due to the centrifugal force to which they are subjected during rotation. The blades are subjected to bending stresses due to the centrifugal force and, as their section is approximately determined by the conditions of flow of the driving medium, i. e. the steam, the length must be limited so that the stresses arising in the outer portions of the blades due to the bending stresses lie within permitted limits. It is evident, however, that, under such conditions, the strength of the material of the blade lying radially inward with respect to said portions, as in the central part of the blade, will not be fully utilized, as the stresses created in the central part on account of the centrifugal force (and arising from bending stresses) are considerably smaller than the stresses in the outer portions.

The present invention has for its object to render it possible to more rationally utilize the whole cross-section of a blade of the type above referred to for taking up stresses arising from the centrifugal force, and to this end I provide radial flow blades so constructed and arranged that only tension stresses or only compression stresses arise in the same, which stresses are uniformly or practically uniformly distributed over a cross-section of the blade taken anywhere along the length of the blade.

The invention will be more fully described with reference to the embodiments thereof illustrated on the accompanying drawings, in connection with which further features characterizing the invention will be set forth.

In the drawings, Fig. 1 is an axial sectional view of part of a rotor constructed according to the invention; Fig. 2 an elevation of the same seen from below in Fig. 1; Fig. 3 is a cross section of part of a rotor illustrating the manner of securing blades and stays, respectively, to supporting annular members; Fig. 3*a* is a cross-sectional view taken on the line 3*a*—3*a* of Fig. 3; Fig. 3*b* is a cross-sectional view taken on the line 3*b*—3*b* of Fig. 3; Fig. 4 is a cross section of the blades and the stays taken on the line 4—4 in Fig. 3; Fig. 5 is a section taken on the line 5—5 in Fig. 3 illustrating thickening of the blades and the stays, respectively, at their fastening places; Fig. 6 is a cross-sectional view taken on the line 6—6 in Fig. 1; and

Figs. 7 and 8 illustrate an embodiment of the invention including straight stays.

Referring more particularly to Figs. 1 through 6, reference character *a* designates turbine blades which may be secured in known manner to rotatable auxiliary spaced annular supporting or retaining members or rings *b*, for instance, by welding or rolling. Two annular members *b* and the blades connected thereto constitute a rotor. The steam flow is in generally radial direction through the rotor. As is well known, a radial flow turbine includes a number of such rotors which are alternately connected to aligned shafts which rotate in opposite directions. According to the invention, said blades have such a shape (in the present case a shape bent outwards in relation to the center of rotation of the rotor) and are so supported that stresses in the same due to the centrifugal force are substantially taken up by tension stresses only, which are distributed evenly or approximately evenly over the cross-section of the blade. On account of the stresses increasing at the end portions of the blades, the cross sections of said blades preferably increase towards the end portions, or the blades may be reinforced at their end points, i. e. at their places of fastening in the annular members *b*, as shown at 2 in Fig. 5.

As clearly shown in the drawings, the blades preferably have parallel outwardly curved inlet and outlet edges and the cross-sections taken normal (that is, perpendicular) to the aforesaid edges, are of equal area for all or a greater portion of the length of the blade. Referring to the cross-section shown in Fig. 3*a*, if this were a cross-section of a straight axially extending blade in a Ljungström radial flow turbine of generally known construction, a stress diagram of forces acting on this area would give a force line crossing the line of zero stress; whereas with blades in accordance with the present invention, a corresponding stress diagram would give a force line parallel to the line of zero stress.

It is to be observed that, in blades constructed in the manner above set forth, the tension stresses created by the centrifugal force will have a tendency to draw the annular members *b* toward each other. In order to counteract this tendency, I provide stays *c* so formed as to maintain the mutual position of the annular members; that is, to maintain the annular members a fixed distance apart. In the present case the stays are so formed that, on account of the centrifugal force, compression stresses will arise in the same having a tendency to move the annular members *b* away from each other, thus counteracting the action on said members of stresses in the blades *a*. The different parts, i. e. the blades and the stays, may be so dimensioned or arranged, respectively, that, as shown in Fig. 3, the components P and Q directed at right angles to the plane of rotation of the annular members balance each other so that said stresses result in radially directed forces R acting upon said annular members.

Preferably the stays are arranged in zigzag fashion between the annular members, as seen in radial direction, at an oblique angle of fastening to the plane of rotation of said annular members, resulting in a particularly firm structure with a high critical speed for the rotor, so that a rotor constructed in this manner may without difficulty be used also at considerably high speeds of revolution. Preferably the stays have a so called drop or stream-line cross-section as shown in Figs. 3 and 4.

In rotors having long blades or stays, respectively, reinforcing bands *d* may be provided, for instance in the manner shown in Figs. 1, 2, 6, in order to counteract a vibration of the vanes or the stays, respectively.

An effect similar to that above described would be obtained, if the blades, instead of being bent outwardly from the center of rotation, are bent inwardly. In this case compression stresses only would arise in the blades instead of tension stresses, and, as a consequence of this, the stays in this case should be bent outwardly so that corresponding tension stresses arise in the stays.

In Figs. 7 and 8 another embodiment of the invention is shown. Fig. 7 shows a cross-section through a number of rotors of a turbine of the so-called double rotating type designed for a high number of revolutions and for a high capacity and Fig. 8 shows a projection of one rotor carried out in accordance with the invention and seen from the center of rotation outwardly, with the blades omitted. This rotor comprises a number of outwardly bent blades *a* which at their ends are attached to elements b. Upon rotation of the turbine, the centrifugal forces cause annular blade retaining members or stresses in these blades as above described, which stresses tend to draw the ring elements *b* toward each other. In order to counterbalance this, stays *c* are arranged between said ring elements which stays in this embodiment are straight or substantially straight but, as above described, are arranged with an oblique angle with respect to the plane of rotation of annular member *b* of the rotor. For the purpose of taking up the stresses originating from the centrifugal forces on these stays and for the purpose of increasing their strength they are attached to circumferential carrying rings *e* as illustrated in Fig. 8.

The blades *a* in the outermost rotors are, as will appear from Fig. 7, bent outwardly to a high degree for the purpose of obtaining a large outlet area for the driving medium, i. e. for the steam in a steam turbine.

This heavy outward bending does, however, not require any particular attachment of the blades to the ring elements *b*, but this attachment may be effected in manner known per se.

By the aid of the invention rotors may be constructed which enable the building of double rotating turbines with radial or nearly radial steam flow for 3000 revolutions per minute and with outlet areas in the last rotor of up to 4 m^2 and more allowing a power output of more than 20,000 kw.

It is to be observed that the invention is not limited to the embodiment of the same described above but includes also other constructions falling within the invention.

Having thus described my invention, what I claim is:

1. In a turbine, a rotor comprising axially spaced supporting members and a plurality of blades secured to and extending between said members, said blades having axially curved inlet and outlet edges, the conformation of said blades being such that stress

therein due to centrifugal force, on rotation of the blades, is substantially uniformly distributed over and at right angles to any cross-section of minimum area.

2. In a turbine, a rotor comprising axially spaced supporting members and a plurality of blades secured to and extending between said members, said blades having parallel and axially curved inlet and outlet edges, the conformation of said blades being such that tensional stress substantially uniformly distributed over the entire cross-sectional area of any cross-section perpendicular to said edges is imposed thereon by centrifugal force due to rotation of the blades.

3. In a turbine, a rotor comprising axially spaced supporting members and a plurality of blades of substantially uniform width at cross sections normal to an axially extending edge thereof, said blades being secured to said members and disposed therebetween, the central portions of said blades being at a different radial distance from the axis of rotation than the ends of the blades and means providing a radial flow of fluid to said blades.

4. In a turbine, a rotor comprising spaced supporting members and a plurality of blades of substantially uniform width at cross sections normal to an axially extending edge thereof, said blades being secured to said members and disposed therebetween, the end portions of the blades being radially nearer the axis of rotation than the intermediate portions, and means providing a radial flow of fluid to said blades.

5. In a turbine, a rotor comprising spaced supporting members and a plurality of blades of substantially uniform width at cross sections normal to an axially extending edge thereof, said blades being secured to said members and disposed therebetween at an angle to a plane normal to the axis of rotation of the turbine, said vanes being curved radially outwardly intermediate the ends thereof.

6. In a turbine, a rotor comprising axially spaced supporting members and a plurality of blades secured to and extending between said members and having their end portions oblique to a plane normal to the axis of rotation of the turbine, said blades transmitting to said members, due to centrifugal force, forces having axial components, and a plurality of stays between said members for counteracting the axial components of said forces.

7. In a turbine, a rotor comprising axially spaced supporting members, a plurality of blades and a plurality of stays, said blades and said stays being secured to said members and disposed therebetween and having their end portions oblique to a plane normal to the axis of rotation of the turbine, the blades being bent radially in one direction intermediate their ends and the stays being bent radially in the opposite direction intermediate their ends.

8. In a turbine, a rotor comprising axially spaced supporting members, a plurality of blades and a plurality of stays, said blades and said stays being secured to said members and disposed therebetween and having their end portions oblique to a plane normal to the axis of rotation of the turbine, the blades being bent radially outwardly intermediate their ends, and the stays being bent radially inwardly intermediate their ends.

9. In a turbine, a rotor comprising axially spaced supporting members, a plurality of blades having curved edges and a plurality of stays secured at their ends to said members, said blades and said stays having their respective ends disposed equidistant from the axis of rotation of the turbine and arranged so that the axial components of forces exerted on said members by the blades due to rotation of the blades are balanced by substantially equal and opposite axial force components exerted on said members due to rotation of the stays.

10. In a turbine, a rotor comprising axially spaced supporting members, a plurality of blades secured at their ends to said members and disposed therebetween and having their end portions at an angle to the axis of rotation, and a plurality of oblique stays secured at their ends to said members and disposed therebetween.

11. In a turbine, a rotor comprising axially spaced supporting members, a plurality of blades secured at their ends to said members and disposed therebetween and having their end portions at an angle to the axis of rotation, said blades being bent radially outwardly intermediate their ends, and a plurality of stays secured at their ends to said members, said stays being equi-distant radially from the axis of rotation throughout their length.

12. In a turbine, a rotor comprising a pair of axially spaced supporting members, a plurality of blades secured at their ends to said members and disposed therebetween and having their end portions oblique to a plane normal to the axis of rotation, said blades being bent so that centrifugal force acting thereon due to rotation produces tension in said blades, and a plurality of stays secured at their ends to said members and disposed therebetween and having their end portions at an angle to a plane normal to the axis of rotation, said stays being bent so that centrifugal force acting thereon due to rotation produces compression in said stays.

13. In a turbine, a rotor comprising axially spaced supporting members and a plurality of blades secured at their ends to said members, said blades each having curved inlet and outlet edges in an axial direction and said

blades being thicker peripherally at their ends than at their central portions.

14. In a turbine, a rotor comprising axially spaced supporting members, a plurality of elements including blades and stays secured at their ends to said members, said blades each having curved inlet and outlet edges in an axial direction, and vibration preventing means circumferentially associated with some of said elements intermediate their ends.

15. In a turbine, a rotor comprising axially spaced supporting members, a plurality of blades and a plurality of stays secured at their ends to said members, said blades each having curved inlet and outlet edges, and means circumferentially engaging said stays intermediate their ends.

16. In a turbine, a rotor comprising axially spaced supporting members, a plurality of blades and a plurality of stays secured at their ends to said members, said blades each having curved inlet and outlet edges, and a plurality of circumferentially arranged bands contacting said stays intermediate their ends.

17. A turbine comprising rotatable blade retaining members, means to axially space said retaining members, blades extending between and having their ends secured to said retaining members, said blades having inlet edges and outlet edges, and said inlet and outlet edges being both curved to form arcs between said retaining members, and means providing a radial flow of fluid to said blade.

18. A turbine comprising rotatable blade retaining members, stay means for axially spacing said retaining members, and blades extending between and having their ends secured to said retaining members, said blades having inlet edges and outlet edges, and said inlet and outlet edges being both curved to form arcs between said retaining members, said blades being so formed as to be subject substantially only to tension stress, and said stay means being under compression stress.

19. A turbine comprising rotatable blade retaining members, means to axially space said retaining members, blades extending between and having their ends secured to said retaining members, each of said blades having lengthwise curved inlet and outlet edges, and means providing a radial flow of fluid to said blades.

20. A turbine comprising rotatable blade retaining members, a web structure for axially spacing said retaining members, and blades extending between and having their ends secured to said retaining members, said blades having lengthwise curved inlet and outlet edges, and cross-sections of uniform area normal to said edges, the blades being so formed that stress therein due to centrifugal force is substantially uniformly distributed over any of said cross-sections.

21. A turbine comprising rotatable blade retaining members, means to axially space said retaining members, and blades extending between and having their ends secured to said retaining members, said blades having inlet and outlet edges, said inlet and outlet edges being both curved to form arcs between said retaining members, and said blades being of greater cross-sectional area adjacent the ends than intermediate the ends.

In testimony whereof I have affixed my signature.

FREDRIK LJUNGSTRÖM.