Aug. 24, 1926. 1,597,467

F. HODGKINSON

TURBINE BLADING

Filed Sept. 12, 1923 3 Sheets-Sheet 1

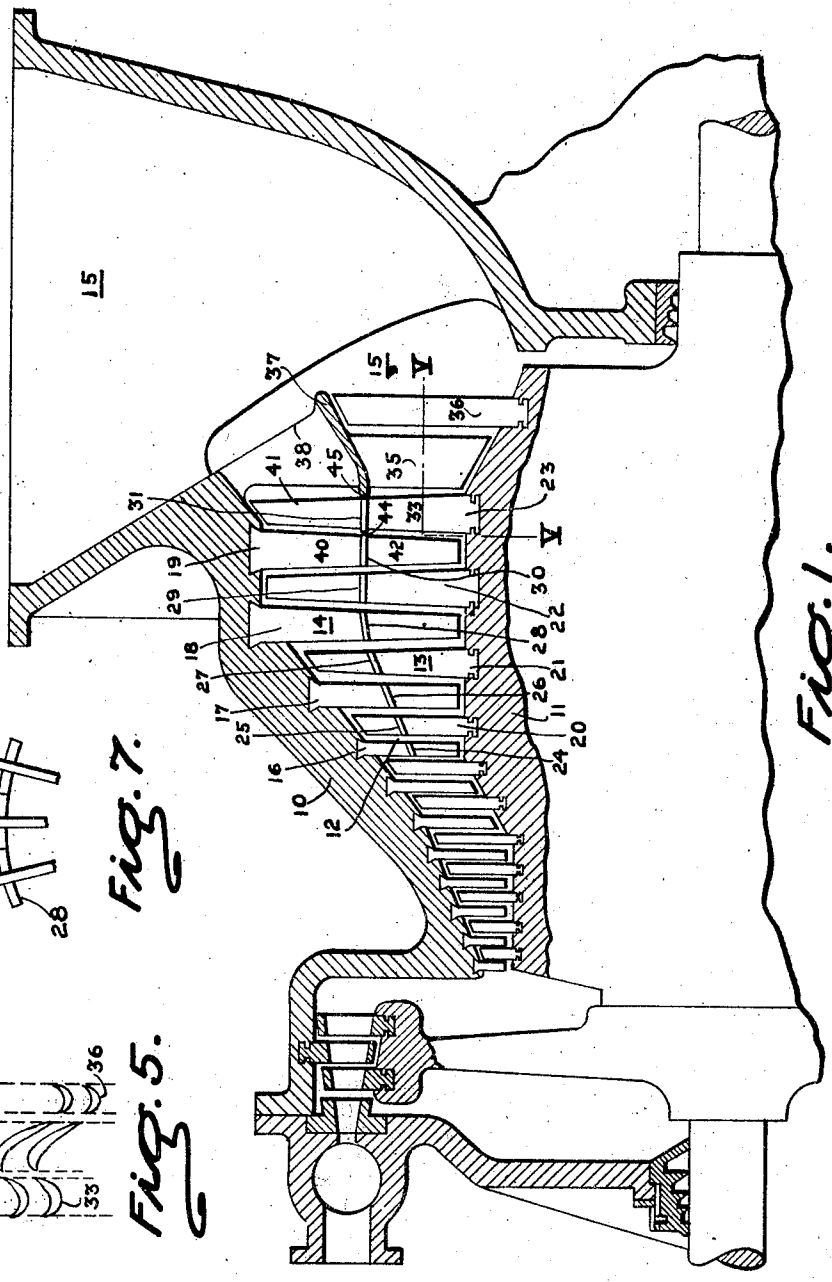


Fig. 1.

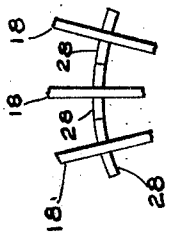


Fig. 7.

Fig. 5.

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TURBINE BLADING

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Fig. 2.

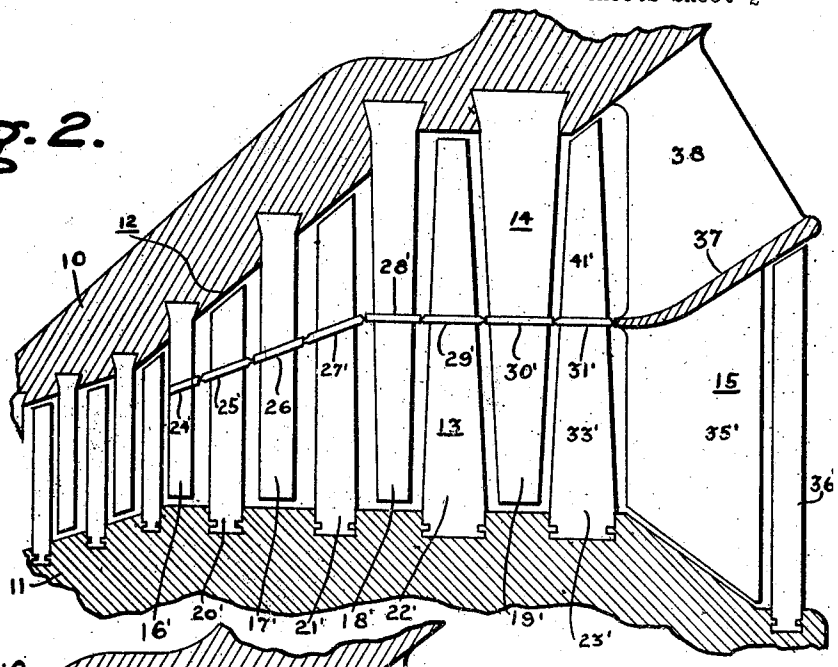
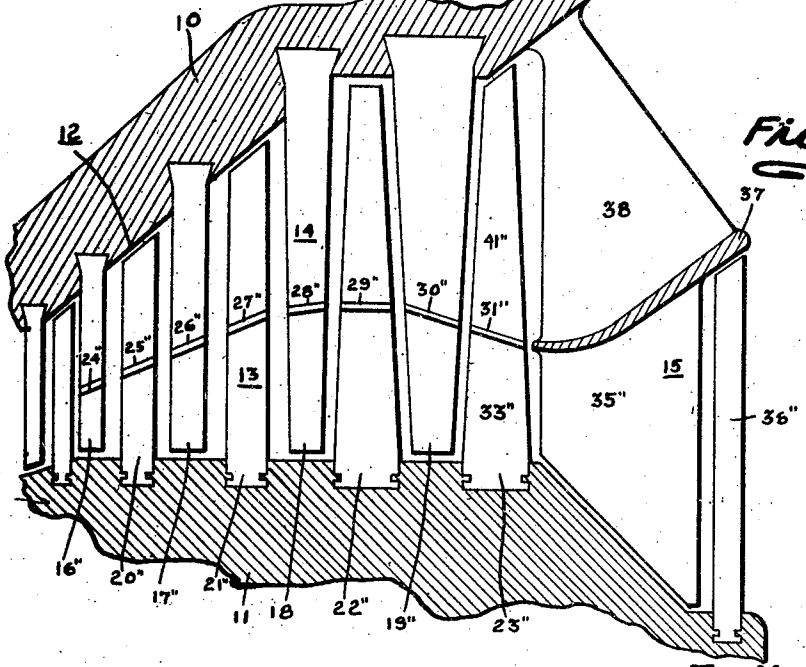


Fig. 3.



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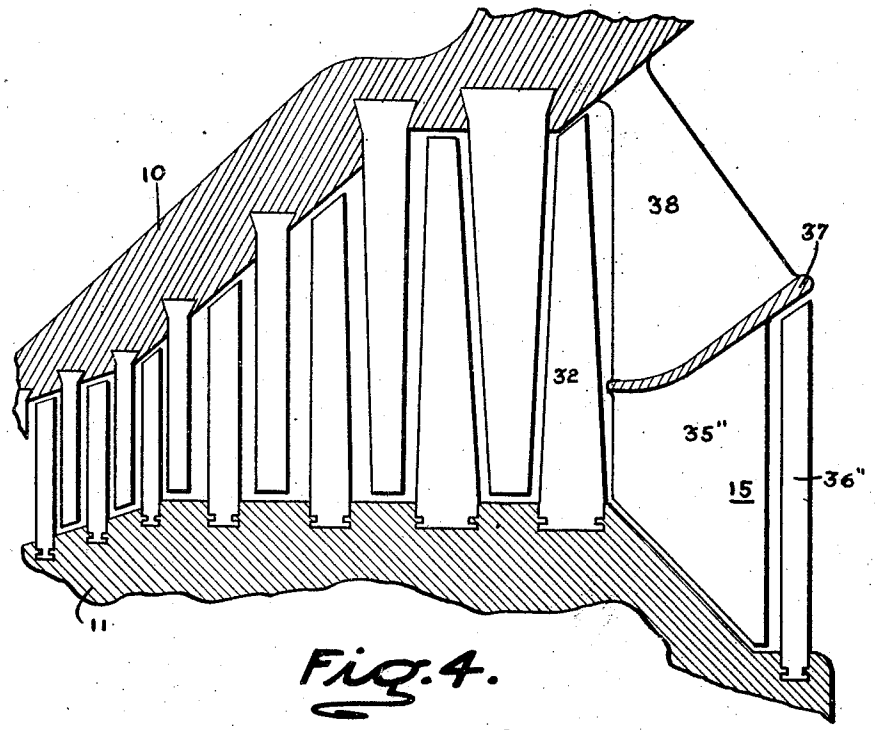


Fig. 4.

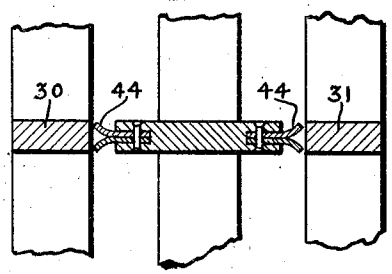


Fig. 6.

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UNITED STATES PATENT OFFICE.

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TURBINE BLADING.

Application filed September 12, 1923. Serial No. 662,324.

My invention relates to elastic-fluid turbines, more particularly to low-pressure blading therefor, and it has for its object to provide apparatus of the character designated wherein terminal losses may be reduced or the capacity of the turbines for the production of power increased.

The height of turbine blades for a given drum diameter is limited from the standpoint of efficiency, on account of the difference in speeds between the tip and root portions thereof which cannot be efficiently satisfied by a single steam velocity. In accordance with my invention, I provide additional or shorter blading following tall low-pressure blading and which serves to abstract the available portion of the residual energy possessed by steam discharged from the inner portions of the tall low-pressure blading.

Preferably, when the differences between tip and root speeds of the blading exceeds a desired amount, partition members are provided which divide the blades into inner and outer tiers and which segregate the steam passing therethrough into inner and outer portions or annuli. This arrangement provides two turbine paths, the blading of which operates at different velocities. Owing to the higher blade velocity of the outer tier, the steam in the outer path or annulus may have sufficient turbine elements moving at a suitable velocity with respect to the steam velocity to abstract the maximum amount of the available energy from the outer annulus or path of steam, whereas, the inner tier, due to its lower blade velocity, cannot abstract the same amount of energy as the outer tier in the same number of rows. Additional blading is, therefore, provided to abstract the available portion of the residual velocity energy from the inner portion of steam discharged from the inner portions of the blades of the last tall moving row.

While low-pressure turbine sections consisting of tiered blading to provide separate turbine passages are old, as may be seen from the patent to Baumann, reissued on April 26, 1921, No. 15,092, original Patent No. 1,302,282, dated April 29, 1919, and assigned to the Westinghouse Electric and Manufacturing Company, yet, so far as I am aware, I am the first to provide blading which is made in tiers in order to avoid terminal losses due to differences in speed between the moving blade tip and root portions. In the Baumann patent referred to, the object is to provide greater leaving area for the terminal moving blades so that terminal blading having smaller and more efficient exit or discharge angles may be employed. Hence, in the Baumann construction, the inner tiers, until the terminal stages are reached, serve, in effect, merely as conduits for supplying steam to the latter. On the other hand, in my construction, since my object is to reduce terminal losses, incident to velocity differences of root and tip portions of blading, which is relatively tall for a given drum diameter, the inner tier is effective in absorbing energy from the steam; and, preferably, the effectiveness of my inner tier is limited only by the necessarily slower moving blade elements thereof as compared to the outer tier.

Apparatus embodying features of my invention is illustrated on the drawings, forming a part of this application, in which Fig. 1 is a sectional view of a turbine showing my improved form of blading applied thereto; Figs. 2 and 3 are views similar to Fig. 1, but showing slightly different modified forms of blading; Fig. 4 shows a further modified form of my invention in which the partition members for the tall blading are omitted; Fig. 5 is a sectional line taken along the line V—V of Fig. 1; Fig. 6 is a detail view showing packing suitable for use in certain of the constructions referred to and Fig. 7 is a view along a row of tiered blades illustrating the partition wall elements defining the tiers.

Referring now to the drawings for a better understanding of my invention, I show in Figs. 1, 2, and 3 a turbine consisting of a casing 10 and a rotor 11 having blading of any suitable type followed by a tiered section, at 12, having inner and outer tiers of blade elements, at 13 and 14, respectively. The inner tier of blade elements, at 13, is followed by additional blading, at 15, for abstracting the available portion of the residual energy from steam discharged from the inner tier.

Referring now more particularly to Fig. 1, I show the tiered section, at 12, comprised by rows of stationary blades 16, 17, 18 and

19 carried by the casing 10 and followed respectively, by the moving rows of blades 20, 21, 22 and 23. The blades 16, 17, 18, 19, 20, 21, 22 and 23 are, respectively, provided with partition or wall elements 24, 25, 26, 27, 28, 29, 30 and 31 which cooperate to define said inner and outer tiers, at 13 and 14, respectively.

The inner portions 33 of the last row of moving blades 23 is followed by the additional blading, at 15, consisting of stationary guide blades 35 followed by a row of blades 36 carried by the rotor 11. The guide blades 35 are carried by a shroud element 37 which also serves as a deflector for the annulus of steam discharged by the outer tier blading and as a shroud or cover for the tips of the blades 36. The shroud element 37 is preferably supported from the casing 10 by means of webs 38 which do not interfere with the free discharge of steam from the outer tier, at 14.

The outer portions 40 and 41 of the stationary and moving blades 19 and 23, respectively, may be of the impulse type, the last drop in pressure for the outer tier, at 14, taking place through the outer blade portions 40. The inner portions 42 and 33 of the rows of blades 19 and 23 may each have drops in pressure or expansion of steam thereacross, in which case the pressure at the discharge side of the blade portions 42 would be greater than the pressure at the discharge side of the blade portions 40 of the same row of stationary blades 19, thereby necessitating the use of packing 44 between the partition or wall elements 30 and 31 to prevent leakage from the inner tier, at 13, to the outer tier, at 14.

The inner blade portions 33 of the row of blades 23 may expand steam to exhaust pressure, namely, the discharge pressure of the outer portions 41 of the same row of blades 23, in which case the blades 35 serve merely as redirecting vanes to properly impinge steam against impulse blades 36; however, as illustrated in Fig. 1, a drop in pressure or expansion of steam is contemplated across the row of blades or vanes 35, in which case, the discharge pressure of the inner blade portions 33 is higher than the pressure of the outer portions 41 of the same row of blades 23, thereby necessitating the employment of packing 45 between the partition or wall elements 31 and the detector or shroud element 37 to prevent steam discharged by the inner blade portions 33 from leaking directly to the exhaust.

The blades or vanes 35 increase in height from the inlet to the exit sides in order to provide for adequate flow area and the discharge of steam at a small angle, the latter feature resulting in narrowing of steam passages as will be clear from Fig. 5, from which it will be seen that the normal passage width decreases from the inlet to the exit sides of the blades or vanes 35. The blade portions 41 and the blades 36 increase in height from the inlet to the exit sides thereof sufficiently to provide adequate area for the passage of steam owing to the decreasing velocity of the latter as it passes therethrough.

In Fig. 2, I show a modified form of my invention in which all of the blading is of the reaction type. In other words, the blade portions 35′, 36′ and 41′ are of the reaction type, that is, a drop in pressure of steam takes place across each of these rows. Since the inner tier, at 13, and the additional blading, at 15, constitute a greater number of energy-abstracting stages than are in the outer tier, at 14, the pressure distributions must be different, that is, the pressures at the discharge sides of the blades 16′, 17′, 18′ and 19′ in the inner tier are greater than the pressures at the discharge sides of these blades in the outer tier, thereby necessitating the use of packing in connection with the partitions 24′, 25′, 26′, 27′, 28′, 29′, 30′ and 31′ and the deflector 37 to minimize leakage from the inner to the outer tier.

Owing to the unavoidable leakage from the inner tier, at 13, to the outer tier, at 14, in the construction shown in Fig. 2, where blading is of the reaction type, I preferably locate the initial partition element 24′ nearer to the tip of the row of blades 20′ than with the construction shown in Fig. 1, in order that a greater annulus inlet area may be provided for the inner tier 13, than the annulus inlet area provided for the outer tier, at 14. Steam which leaks from the inner tier, at 13, is added to that passing through the outer tier, at 14, so that substantially equal amounts may be discharged by the inner and outer portions of the last row of moving blades 23′.

In Fig. 2, the blade elements 41′, 35′ and 36′ increase in height from the inlet to the exit sides to provide for adequate area due to the expansion of steam and to the discharge thereof at an angle. While I have particularly described the low-pressure blading of Fig. 2 as being of the reaction type, it is to be understood that this is done by way of example only and that impulse blading could be employed just as well and my additional blading would cooperate just as usefully.

In Fig. 3, I show a further modified form of my invention in which the blading of the inner and the outer tiers, at 13 and 14, of the tiered section, at 12, is of the reaction type and in which the same pressure distribution is provided for, that is, the discharge pressures of outer portions 41″ and the inner portions 33″ of the last row of moving blades 23″ are the same and the inlet pressures of the inner and outer portions

of the first row of tiered blades 16″ are the same. Since the pressures at the discharge sides of the rows of blades 20″, 21″, 22″ and 23″ in the inner and in the outer tiers, at 13 and 14, respectively, are equal, it is unnecessary to use packing in connection with the diaphragm or partition element 24″, 25″, 26″, 27″, 28″, 29″, 30″ and 31″ and with the deflector or shroud element 37 to prevent leakage of steam from the inner tier, at 13, to the outer tier, at 14. Even though the discharge pressures are uniform throughout the length of the last row of moving blades 23″, steam will be discharged from the inner portions 33″ with a greater residual velocity energy than steam discharged by the outer portions 41″ of the same row of blades 23″ owing to the lower blade velocity of the inner portions 33″.

As steam reaches the exhaust or terminal pressure after it is discharged from the inner blade portions 33″, the blades 35″ merely serve as directing blades to properly impinge the inner annulus of steam against the impulse blades 36″ in order that the available portion of the higher residual velocity energy possessed by steam of the inner annulus may be abstracted.

In order to avoid excessive gauging of the blading of the outer tier, at 14, in Fig. 3, so as to maintain high efficiency for the blading of the outer tier, the partition members 24″, 25″, 26″, 27″, 28″, 29″, 30″ and 31″ and the deflector 37 may be so located as to provide adequate area for the outer annulus with the preservation of small discharge or exit angles for the rows of moving blade elements of the outer tier, at 14. The location of the partition elements further inward as the exhaust is approached in this way, of course, necessitates a contraction in the area of the inner annulus of the inner tier, at 13. Such contraction may be compensated for by proper gauging of the blade elements of the inner tier, at 13, the high residual velocity energy of the steam discharged by the inner tier or blading, at 13, being abstracted by the last row of impulse blades 36″ of the additional blading, at 15.

The blades 35″ increase in height from the inlet to the discharge sides sufficiently to compensate for the narrowing of the steam passages therebetween incident to discharge at small angles.

In Fig. 4, I show a further modified form of my invention in which the additional blading, at 15, is similar to that used in Fig. 3. In this view, the last row of moving tall blades 32 and preceding rows of blades are not tiered, as shown in Figs. 1, 2 and 3. With this type of construction, it is essential that the pressure distribution shall be uniform throughout the blading, in other words, the discharge pressure must be the same throughout the discharge side of the last row of moving blades 32. The additional blading consists of a row of guide blades or vanes 35″ carried by a deflector 37, as in Fig. 3, for properly directing steam for impingement against the row of impulse blades 36″. As already pointed out, while the pressure distribution may be the same, nevertheless, with blading having a high ratio of blade height to blade diameter, the best operating efficiency can not be maintained throughout the height of the blade. Hence, in this modification, as well as those already described, I design the blading so that the outer portions thereof shall move at such a speed with respect to the steam speed as to result in the best energy abstraction, additional blading being employed at the discharge side of the inner portions of the last row of moving blades in order that the necessarily higher residual energy of steam discharged by the inner portions may be abstracted.

It is possible, with my improved type of turbine, to provide for uniform velocity ratios in the inner and in the outer tiers. For example, in Fig. 2, the ratio of blade speed to steam speed may be uniform throughout the blading elements of the outer tier, at 14, and the velocity ratio may be uniform throughout the blading of the inner tier, at 13, and the additional blading, at 15.

In any of the constructions aforesaid, whenever the discharge pressure for the inner portions of a row of blades is different from the discharge pressure of the outer portions of the same row, it is necessary to employ packing in order to minimize leakage from one tier to the other. Such packing is shown in Fig. 6. In this view, I show members 44 carried by partition elements in order to limit leakage. The packing shown in Fig. 6 is of the well-known type. It is to be understood that any other suitable form of packing may be used in this relation for the same purpose.

The operation of apparatus made in accordance with my invention will be apparent from the foregoing description. Steam passes through the turbine in the ordinary way, but owing to excessive differences between the tip and root speeds of the blading at the low-pressure end, steam is discharged from the inner portions of the last row of moving blades with greater residual energy than that discharged from the outer portions of the same row of blades. Hence, in accordance with my invention, the low-pressure blading is so designed that the velocity of the outer blade portions is suitable to the steam velocity and additional blading is employed to abstract the available portion of the residual energy from the steam discharged from the inner portions of the last row of blades referred to. Preferably,

partition elements are provided in order to define separate inner and outer tiers of blade portions and to segregate the steam passing therethrough into inner and outer annuli. This is essential if there is any difference in the pressure distribution as is the case in Figs. 1 and 2 already referred to, wherein packing is shown to minimize leakage from one tier to the other at the discharge sides of blades having different discharge pressures. I prefer to use the diaphragm or partition elements in connection with the low-pressure blading even though the discharge pressures are uniform at the exit sides of each row of blades. However, in some cases, as illustrated in Fig. 4, the partitions may be dispensed with and the available portion of the higher residual velocity energy of the inner portions of the last row of moving blades 36″ may be abstracted by the additional blading, at 15.

From the foregoing, it will be apparent that the low-pressure blading, at 12, may be of any suitable type, that any desired distribution of pressures therein may be employed, and that the additional blading may have the stationary blade elements thereof serve merely as directing vanes or to expand steam further and that the moving blades of the additional blading may be either of the impulse or the reaction type. It is also to be understood that, if desired, more than one moving row of additional blading may be employed. In other words, I desire it to be understood that the additional blading and the tall low-pressure blading may be designed in any suitable manner for the abstraction of energy from steam, and, while I prefer to use partition or diaphragm elements to divide the low-pressure blading into inner and outer tiers and to segregate the steam passing therethrough into inner and outer annuli, it is to be understood that in some cases, as shown in Fig. 4, this feature of construction may be omitted. Hence, I regard my invention to be the provision of additional blading in connection with the inner portions of blading having a high ratio of blade height to blade diameter, the outer portions of the blading having a velocity suitable to the steam velocity and the additional blading serving to abstract the available portion of the residual energy possessed by steam discharged by the inner portions of said high ratio blading; and, more particularly, I regard as my invention the division of blading having a high ratio of blade height to blade diameter into inner and outer tiers, the blading of the outer tier having a velocity suitable to the steam velocity and additional blading being employed to abstract the available portion of the residual energy in the steam discharged by the inner tier.

While I have shown my invention in several 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. In a turbine, the combination of blading having a uniform range of expansion from the roots to the tips thereof, the inner portions of the last moving row of such blading discharging steam with greater residual energy than the outer portions to the extent determined by the relatively lower speed of said inner portions, and additional blading for abstracting the available portion of the residual energy possessed by the steam discharged by said inner portions.

2. In a turbine, the combination of blading having a high ratio of blade height to blade diameter and a uniform range of expansion from the roots to the tips thereof, partition means carried by the blading for dividing motive fluid passing therethrough into inner and outer annuli, and additional blading for abstracting the available portion of the velocity energy possessed by the inner annulus of motive fluid discharged by said first blading.

3. In a turbine, the combination of low-pressure blading comprising a plurality of rows of stationary and moving blades, the last row of moving blades discharging steam at the same pressure from the roots to the tips thereof, partition means carried by such blades for dividing them into inner and outer tiers and for segregating the motive fluid passing therethrough into inner and outer annuli, and additional blading for abstracting the available portion of the residual velocity energy possessed by the inner annulus of motive fluid discharged by the inner tier of said first blading.

4. In a turbine, the combination of low-pressure tiered blading in which substantial energy abstraction takes place in the tiers and in which the inner tier discharges steam with greater residual energy than the outer tier and additional blading following the inner tier for abstracting the available portion of the residual energy possessed by the motive fluid discharged thereby.

In testimony whereof, I have hereunto subscribed my name this 10th day of Sept. 1923.

FRANCIS HODGKINSON.