No. 815,154. PATENTED MAR. 13, 1906.

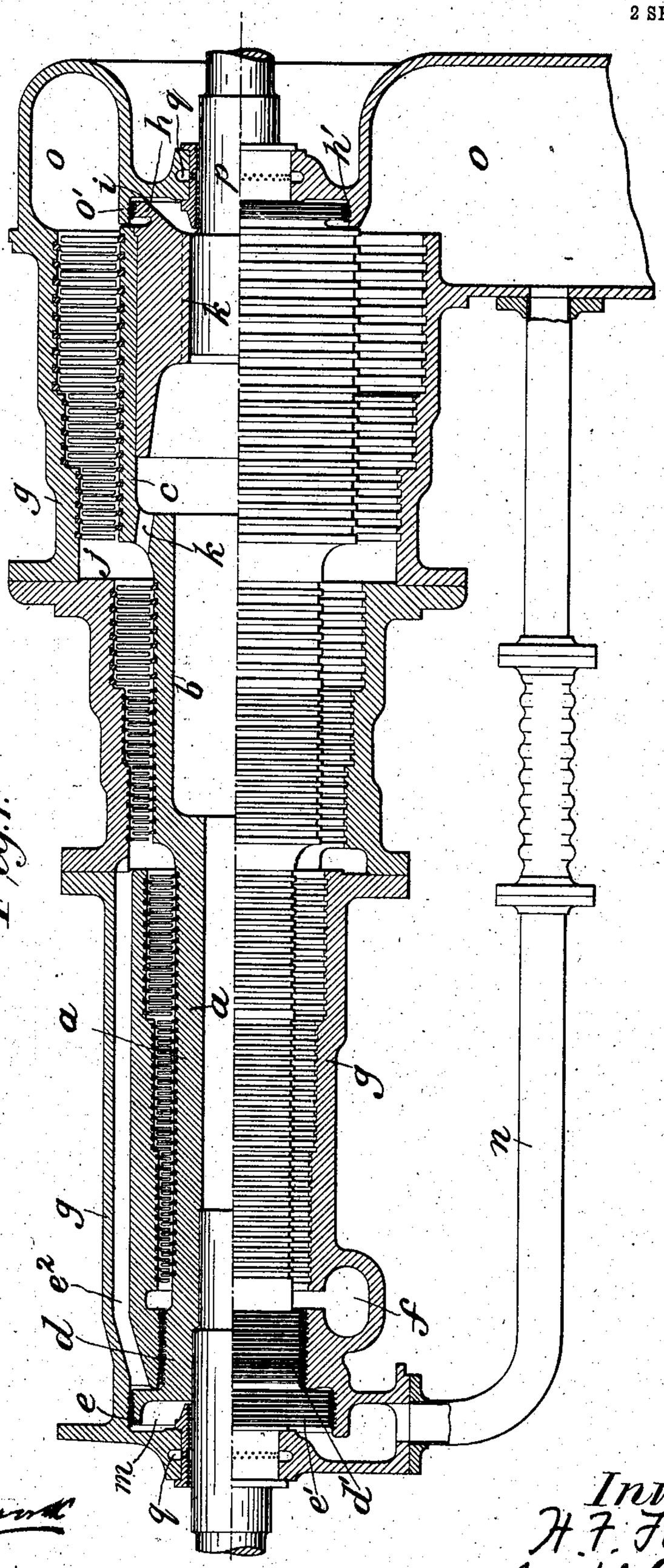
H. F. FULLAGAR.

TURBINE.

APPLICATION FILED AUG. 18, 1904.

2 SHEETS—SHEET 1.

Fig. 1.



Witnesses.

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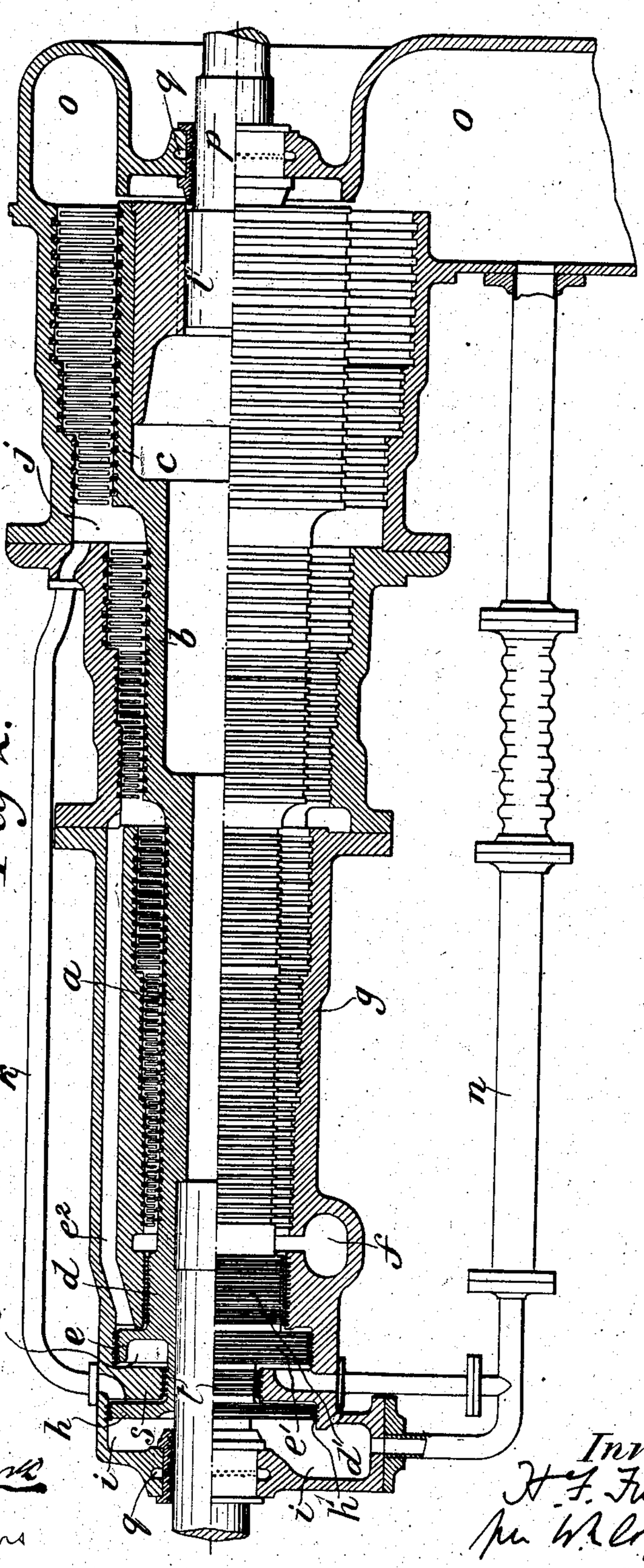

Fig 2.

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UNITED STATES PATENT OFFICE.

HUGH FRANCIS FULLAGAR, OF NEWCASTLE-UPON-TYNE, ENGLAND, ASSIGNOR TO ALLIS-CHALMERS COMPANY, OF JERSEY CITY, NEW JERSEY, A CORPORATION OF NEW JERSEY.

TURBINE.

No. 815,154. Specification of Letters Patent. Patented March 13, 1906.

Application filed August 18, 1904. Serial No. 221,254.

To all whom it may concern:

Be it known that I, HUGH FRANCIS FULLAGAR, a subject of the King of Great Britain and Ireland, residing at Newcastle-upon-Tyne, in the county of Northumberland, England, have invented Improvements in Turbines, of which the following is a specification.

In axial-flow turbines which have several sets of rotary and stationary blades and in which the rotary blades are mounted upon a stepped shaft or drum (hereinafter called the "spindle") increasing in diameter from the inlet to the exhaust it is usual, in order to balance the end thrust of the steam or other working fluid (hereinafter referred to as "steam") upon the rotary rings of blades and annular surfaces of the steps of the spindle, to provide the spindle at its inlet end with similar but reversely-arranged steps the diameters of which correspond to those of the main or working steps carrying the rotary rings of blades plus an amount equal usually to the radial length of the blades in the rings of blades upon those steps or to the mean radial length of the blades in the rings of blades where several rings of blades of different length are used on each step, the reversely-arranged steps being provided in lieu of blades with rotary labyrinth-packing devices, thus forming what are usualy called "balance-pistons," so that the end pressure of the steam upon the annular surfaces of these balancing steps or pistons is equal to and counterbalances the steam-pressure upon the first-mentioned steps and the rotating rings of blades carried thereby. In order to insure that the pressure of steam upon the corresponding working and balancing steps shall be exactly equal during the working of the turbine, the parts of corresponding diameter of the two sets of steps are connected by passages or ports, the outer side of the largest balance-piston being connected with the exhaust. With this arrangement, however, as the balance-pistons have to be made of different diameters that are dependent upon and approximate to the different diameters of the rotary rings of blades in the corresponding sets thereof which they are designed to counterbalance or upon the mean diameters of the rings of blades in the several sets, when the rings of blades in each set are of varying diameter it follows that the turbine-casing has to be made of a stepped shape to accommodate the balance-pistons, and when there are a number of such pistons the casing at the corresponding end of the turbine has to be made of considerable diameter to accommodate the outmost and largest balance-piston, which is objectionable in practice. To obviate this, I have heretofore removed the largest balance-piston from the spindle at the inlet end of the turbine and attached it thereto at the exhaust end at a part thereof adjacent to and inside the outer end wall of the exhaust-chamber located at the outlet end of the last and largest set of rings of blades, such balance-piston being arranged in a chamber the rear or pressure end of which is connected to the steam-space between the last two bladed steps of the spindle, the usual labyrinth-packing being provided between the piston and the wall of the chamber to retard the flow of steam from the piston-chamber to the exhaust-chamber. The front or exhaust end of the chamber containing the balance-piston of next smaller size and located at the inlet end of the turbine was connected, as usual, to the steam-space between the two last bladed steps of the spindle. This arrangement, although it enables the diameter of the inlet end of the turbine-casing to be reduced, requires that the balance-piston for the last bladed portion of the spindle should still be made of large diameter. Furthermore, such an arrangement necessitates the placing of the glands at the two ends of the turbine-casing and the two bearings for the turbine-spindle at a greater distance apart than is necessary in the case of a turbine according to the first-described arrangement and having the same number and diameters of rings of blades, and has consequently necessitated the use of a longer and stronger spindle. Moreover, balance-pistons of large diameter require to be made in one piece with the spindle or to be very firmly attached to the same, thus adding to the cost of manufacture. Furthermore, it is impossible to employ such fine clearances upon large balance-pistons as can be used with smaller ones, both because any deviation or vibration of the spindle causes a greater variation of clearance the larger the piston and also because such pistons having a high peripheral velocity are

liable to cause serious damage if they should come accidentally into hard contact with the part of the casing or cylinder that surrounds them. Also, owing to this high peripheral velocity, the unavoidable presence of water in the packing-grooves causes very considerable friction and loss of power.

Now this invention has for object to obviate the disadvantages above described attending the use of balance-pistons of large diameters. For this purpose in order to counterbalance the end thrust upon the largest step of the turbine-spindle or drum and the blades carried thereon a separate piston is employed, situated, preferably, in a space or chamber at the exhaust end of the turbine and having an effective end or transverse area substantially less than the annular area of the large piston heretofore usually employed for the purpose. This separate piston is therefore of much smaller diameter than the one it replaces. In fact, it is usually smaller than the large end of the spindle, and consequently can be formed at the exhaust end of the spindle adjacent to a portion thereof of reduced diameter without interfering with the passage of steam from the blades to the exhaust-chamber, which in one arrangement surrounds the space or chamber containing the said separate balance-piston. Steam is admitted to the back of this piston between it and the outer end wall of its space or chamber by means of a passage preferably provided within the spindle itself and extending from the steam-space between the last two sets of rotary blades, the free escape of such steam to the exhaust being prevented by a labyrinth-packing device of the kind hereinbefore referred to located between the periphery of the balance-piston and the wall of the adjacent portion of the exhaust-chamber when this chamber surrounds that containing the separate balance-piston. The outer end of the last balance-piston at the inlet end of the turbine is connected with the exhaust, and the labyrinth-packing device therefor may be made of such additional length as is necessary to reduce the leakage at this point to the desired extent. By this arrangement the last balance-piston at the inlet end will counterbalance not only the end thrust upon the corresponding bladed step of the turbine-spindle, but also a portion of the end thrust upon the next or largest bladed step of the spindle, so that the balance-piston for counterbalancing the remaining portion of the end thrust on the largest bladed step can be made of substantially less diameter than heretofore practicable.

The manner of carrying out the invention is illustrated by the accompanying drawings, wherein—

Figures 1 and 2 represent, partly in longitudinal section and partly in elevation with the rings of blades removed, two examples of turbines constructed according to this invention.

In the example shown in Fig. 1 the turbine-spindle comprises three bladed steps *a*, *b*, and *c*. To two of these—namely, *a* and *b*—there correspond balance-pistons *d* and *e*, provided with labyrinth-packing devices *d'* and *e'* of the ordinary type, the pistons *d* and *e* being arranged on the opposite side of the steam-inlet *f* of the turbine-casing *g* to the bladed steps *a* and *b* and the adjacent end surfaces of the bladed step *a* and the piston *d* being in direct communication, while the end surface of the bladed step *b*, facing the effective side of piston *e*, is in communication through a pipe or passage e^2 with this effective side of piston *e*. To balance the end thrust on the inlet end of the bladed step *c*, instead of a balance-piston arranged as an annular step of larger diameter than the piston *e* and at the farther side thereof from the bladed steps *a*, *b*, and *c*, there is employed a piston *h*, separate from the piston *e* and placed in the example now being described in a space or chamber *i* at the exhaust end of the bladed step *c*, that part of the space or chamber *i* that is farthest from the step *c* being in communication with the steam-space *j* between the last two bladed steps *b* and *c* of the spindle through symmetrically-arranged passages *k*, extending through the spindle and the piston, so that the rear end surface of the latter, which is the effective side, is subject to the pressure of the steam in the said space *j*. Also the front end of the space or chamber *m*, containing the balance-piston *e* at the opposite side of the steam-inlet *f*, instead of being in communication with the steam-space *j* between the two last bladed steps of the spindle, as heretofore, is in direct communication by a pipe *n* with the exhaust-chamber *o*. The ineffective side of the piston *e* therefore communicates with the exhaust. The space or chamber *i* containing the balance-piston *h* is separated by an ordinary labyrinth-packing device *h'* between the piston *h* and the inwardly-projecting or reëntrant wall *o'* of the exhaust-chamber *o*, which surrounds the said space or chamber *i*. By this arrangement the end thrust due to a given difference of pressure at the two ends of one bladed step—namely, *c*—of the spindle is balanced by adding this difference of pressure to that acting upon the balance-piston—namely, *e*—which balances the difference of pressure between the two ends of the previous bladed step—namely, *b*—and by applying the same difference of pressure to a separate or additional piston—namely, *h*. In this way the balance-piston *e* balances not only the end thrust on its own bladed step *b* of the spindle, but also part of the end thrust on the bladed step *c*, so that

the separate piston *h* has only to balance the remaining portion of such end thrust. As a result of this arrangement the balance-piston *h* for the largest bladed step *c* can be made with an effective area substantially less than the effective annular area of the balance-piston that would in the ordinary way be provided at the opposite side of the balance-piston *e*, and by fixing such piston *h* on the end portion *p* of the turbine-spindle it can be made so much smaller in diameter than the step *c* that it will not interfere with the passage of steam from the blades of that step into the exhaust space or chamber *o*. Furthermore, the distance apart of the glands *q q* for the turbine-spindle need not be greater than heretofore usual for a turbine of equal power.

To compensate for the absence of a balance-piston at the outer end of the balance-piston *e*, the labyrinth-packing device *e'* for such piston is made of greater length than usual to secure the required retardation of leakage.

The piston *h* instead of being arranged at the exhaust end of the turbine may be arranged at the inlet end thereof, as shown in Fig. 2. In this case, the balance-piston *h* for the larger step of the spindle is arranged in a space or chamber *i*, that is separated from the space or chamber *m* containing the balance-piston *d* by a fixed wall *s* with labyrinth-packing device *t*. The rear side of the piston *h* is in communication through a pipe *k'* with the steam-space *j* between the last two bladed steps *b* and *c* of the spindle. The rear side of the chamber *m* of the piston *e* is in communication through the passage e^2 with the steam-space between the two bladed steps *a* and *b* of the spindle. The front ends of the two chambers *i* and *m* are in communication with the exhaust-chamber *o* through a pipe *n* common to them. This arrangement acts in the same way as that shown in Fig. 1, the end thrust on the largest bladed step *c* of the spindle being balanced partly by the piston *e* and partly by the piston *h*, which is secured upon the reduced forward end *p* of the turbine-spindle and is for a given size of turbine made of much smaller diameter than the ordinary balance-piston, which it replaces.

The details of construction may be altered without departing from the essential features of the invention.

I claim—

1. In a longitudinal-flow turbine, a bladed casing, a bladed spindle therein comprising a plurality of steps, an equal plurality of balance-pistons therefor, a separate chamber in the casing for one of said balance-pistons, a separate exhaust-communication for said separate chamber, and a communication for said separate chamber to the working passage of the turbine intermediate the inlet and exhaust thereof.

2. In a longitudinal-flow turbine, a bladed spindle comprising a plurality of steps, an equal plurality of balance-pistons therefor, a chamber for one of the pistons, a separate stepped chamber for the remaining pistons, and ducts connecting the chambers to various points along the working passage of the turbine.

3. In a longitudinal-flow turbine, the combination of a bladed casing, a bladed spindle therein, separate chambers in the casing, balance-pistons in the chambers, and ducts for connecting the chambers to various points along the working passage of the turbine.

4. In a longitudinal-flow turbine, the combination of a bladed casing, a bladed spindle therein, separate chambers in the casing, balance-pistons in the chambers, separate ducts for connecting the chambers to various points along the working passage of the turbine including immediately separate ducts connecting the chambers to the exhaust.

5. In a longitudinal-flow turbine, the combination of a bladed casing, a bladed spindle therein, and a plurality of pistons subjected to different pressures for balancing endwise thrust, one of the lower pressure-subjected pistons having the inner margin of its effective surface of less diameter than the outer margin of the effective surface of any other piston.

6. In a longitudinal-flow turbine, the combination of a bladed casing, a bladed spindle therein comprising a plurality of steps, and a plurality of pistons for balancing endwise thrust, one of the pistons having its effective surface nearer the axis than its corresponding step-surface.

7. In a longitudinal-flow turbine, the combination of a bladed casing, a bladed spindle therein comprising a plurality of steps, an equal plurality of balance-pistons therefor, a chamber for one of the pistons, a separate stepped chamber for the remaining pistons, ducts connecting the chambers to various points along the working passage of the turbine, and the solitary piston having the inner margin of its effective surface of less diameter than the outer margin of the effective surface of the largest of the remaining pistons.

8. In a longitudinal-flow turbine, the combination of a bladed casing, a bladed spindle therein comprising a plurality of steps, a balance-piston subject on one face to admission-pressure for the blades of a smaller step, and a balance-piston having the inner margin of its effective surface of less diameter than the outer margin of the effective surface of the former balance-piston and subject on one face to admission-pressure for the blades of a larger step.

9. In a longitudinal-flow turbine, the combination of a bladed casing, a bladed spindle therein, a chamber in the casing and removed from the exhaust end thereof, a balance-pis-

ton therein, a chamber in the exhaust end of the casing, a second balance-piston therein, and means for subjecting the second piston to a pressure of steam equal to that at a point intermediate the inlet and exhaust of the turbine.

10. In a longitudinal-flow turbine, the combination of a bladed casing, a bladed spindle therein comprising a plurality of steps, an equal plurality of corresponding balance-pistons therefor, a chamber in the exhaust end of the casing for one of the pistons, means for subjecting said piston to admission-pressure for the blades of the largest step, a composite chamber in the head end of the casing for the remaining pistons, and means for subjecting said pistons to admission-pressures respectively for the blades of the remaining steps.

11. In a longitudinal-flow turbine, the combination of a bladed casing, a bladed spindle therein comprising a plurality of steps, an equal plurality of corresponding balance-pistons therefor, a chamber in the exhaust end of the casing for one of the pistons, ducts in the spindle connecting said chamber and the inlet of the largest step, a composite chamber in the head end of the casing for the remaining pistons, and means for subjecting said pistons to admission-pressures respectively for the blades of the remaining steps.

12. In a longitudinal-flow turbine, the combination of a bladed casing, a bladed spindle therein comprising a plurality of steps, an equal plurality of corresponding balance-pistons therefor, a chamber in the exhaust end of the casing for one of the pistons, said chamber surrounded by the exhaust-space of the turbine, means for subjecting said piston to admission-pressure for the blades of the largest step, a composite chamber in the head end of the casing for the remaining pistons, and means for subjecting said pistons to admission-pressures respectively for the blades of the remaining steps.

13. In a longitudinal-flow turbine, the combination of a bladed casing, a bladed spindle therein comprising a plurality of steps, an equal plurality of corresponding balance-pistons therefor, a chamber in the exhaust end of the casing for one of the pistons, means for subjecting said piston to admission-pressure for the blades of the largest step, a composite chamber in the head end of the casing for the remaining pistons, means for subjecting said pistons to admission-pressures respectively for the blades of the remaining steps, and means for subjecting the unbalanced opposite sides of the pistons to exhaust-pressure.

14. In a longitudinal-flow turbine, the combination of a bladed casing, a bladed spindle therein comprising a plurality of steps, an equal plurality of corresponding balance-pistons therefor, a chamber in the exhaust end of the casing for one of the pistons, said chamber surrounded by the exhaust-space of the turbine, ducts in the spindle connecting said chamber and the inlet of the largest step, a composite chamber in the head end of the casing for the remaining pistons, and means for subjecting said pistons to admission-pressures respectively for the blades of the remaining steps.

15. In a longitudinal-flow turbine, the combination of a bladed casing, a bladed spindle therein comprising a plurality of steps, an equal plurality of corresponding balance-pistons therefor, a chamber in the exhaust end of the casing for one of the pistons, said chamber surrounded by the exhaust-space of the turbine, ducts in the spindle connecting said chamber and the inlet of the largest step, a composite chamber in the head end of the casing for the remaining pistons, means for subjecting said pistons to admission-pressures respectively for the blades of the remaining steps, and means for subjecting the unbalanced opposite sides of the pistons to exhaust-pressure.

16. In a longitudinal-flow turbine, the combination of a bladed casing, a bladed spindle therein comprising a plurality of steps, an equal plurality of corresponding balance-pistons therefor, a chamber in the exhaust end of the casing for one of the pistons, said chamber surrounded by the exhaust-space of the turbine, ducts in the spindle connecting said chamber and the inlet of the largest step, a composite chamber in the head end of the casing for the remaining pistons, and means for subjecting the unbalanced opposite sides of the pistons to exhaust-pressure.

17. In a longitudinal-flow turbine, the combination of a bladed casing, a bladed spindle therein comprising a plurality of steps, a balance-piston subject on one face to admission-pressure for the blades of a smaller step, and a balance-piston at the exhaust end of a larger step and having the inner margin of its effective surface of less diameter than the outer margin of the effective surface of the former balance-piston and subject on one face to admission-pressure for the blades of said larger step.

18. A longitudinal-flow turbine, a casing therefor having chambers, and pressure balance-pistons in said chambers, the turbine-exhaust having communication with the ineffective side of a plurality of pistons.

19. A rotor, balance-piston thereon, a stator, and separate chambers in the stator for the pistons, a plurality of the chambers having communication with the exhaust.

20. A turbine-spindle, a casing therefor having fluid-chambers, a pressure balance-piston in one of the chambers, and means of communication leading through the spindle from one of the other chambers to the effective side of the piston.

21. A turbine having an exhaust-chamber

with stationary reëntrant inner walls, and a pressure balance-piston peripherally coacting with the reëntrant inner walls.

22. A stepped turbine-spindle having a pressure balance-piston of less diameter than the low-pressure portion of the spindle, an exhaust-chamber with stationary reëntrant inner walls said piston coacting with the reentrant inner walls.

23. In a turbine, a rotor, a plurality of bearings therefor, and a pressure balance-piston near each bearing, the ineffective side of a piston being open to exhaust.

24. In a turbine, a casing, a rotor coacting with the casing to form a working passage, balance-pistons on the rotor near its ends, means for placing the effective sides of the pistons in communication with the working passage at different points, and means for placing the ineffective side of a piston in communication with the exhaust.

25. In a turbine, a casing, a rotor coacting with the casing to form a working passage, balance-pistons on the rotor located in separate chambers, means for placing the effective sides of the pistons in communication with the working passage at different points, and means for placing the ineffective side of a piston in communication with the exhaust.

26. In a turbine, the combination of a bladed casing having an inlet for motive fluid and an outlet for exhaust, a spindle located within said casing and comprising bladed annular steps increasing in diameter from said inlet toward said outlet, and a balance-piston for each step, the balance-piston for the step of largest diameter being located in a chamber that is separate from that containing the other balance-piston and has a separate exhaust and is in communication with the interior of the casing at a part thereof between its said inlet and outlet.

Signed at Newcastle-upon-Tyne, in the county of Northumberland, this 21st day of July, 1904.

HUGH FRANCIS FULLAGAR.

Witnesses:

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