No. 815,281.

PATENTED MAR. 13, 1906.

H. F. FULLAGAR.

STEAM TURBINE.

APPLICATION FILED AUG. 18, 1904.

4 SHEETS—SHEET 1.

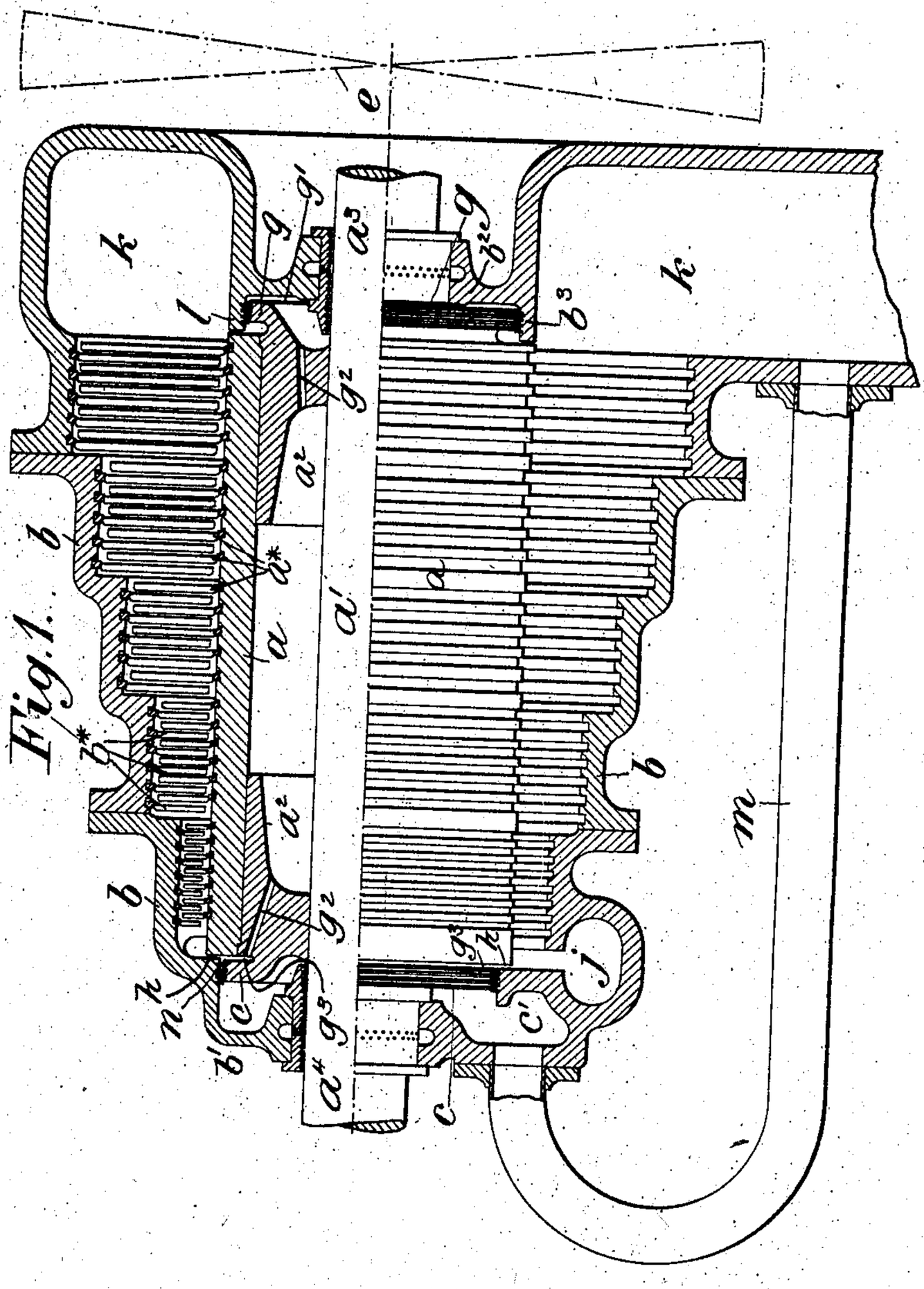

Fig. 1.

Witnesses.
F. Wm. Howard
W. Henry Simms

Inventor:
H. F. Fullagar
per W. Lloyd Wise
Attorney.

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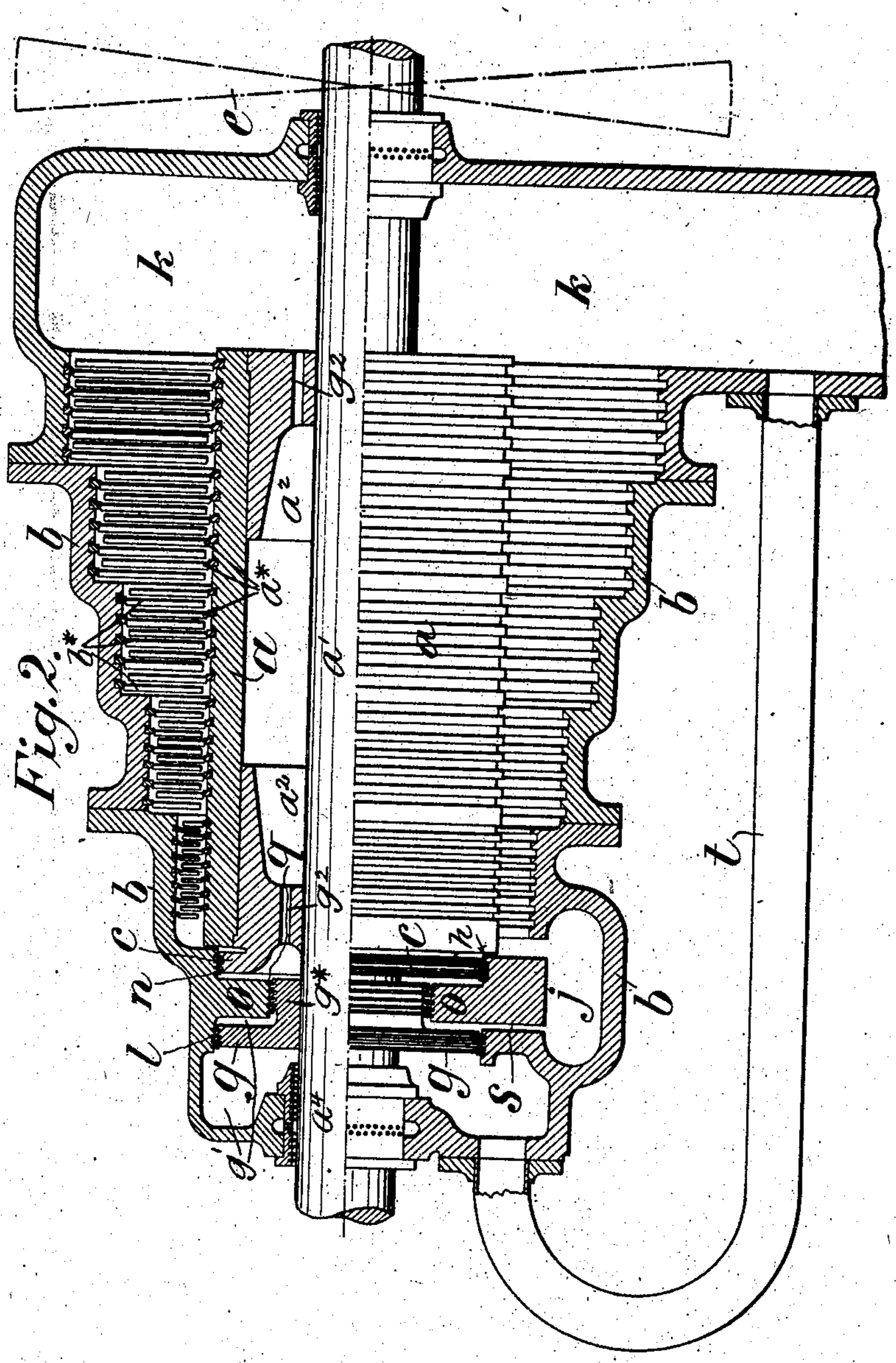
4 SHEETS—SHEET 2.



Witnesses:
F. Mac Howard
W Henry Simms

Inventor:
H. F. Fullagar
per W. Lloyd Wise
Attorney.

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4 SHEETS—SHEET 3.

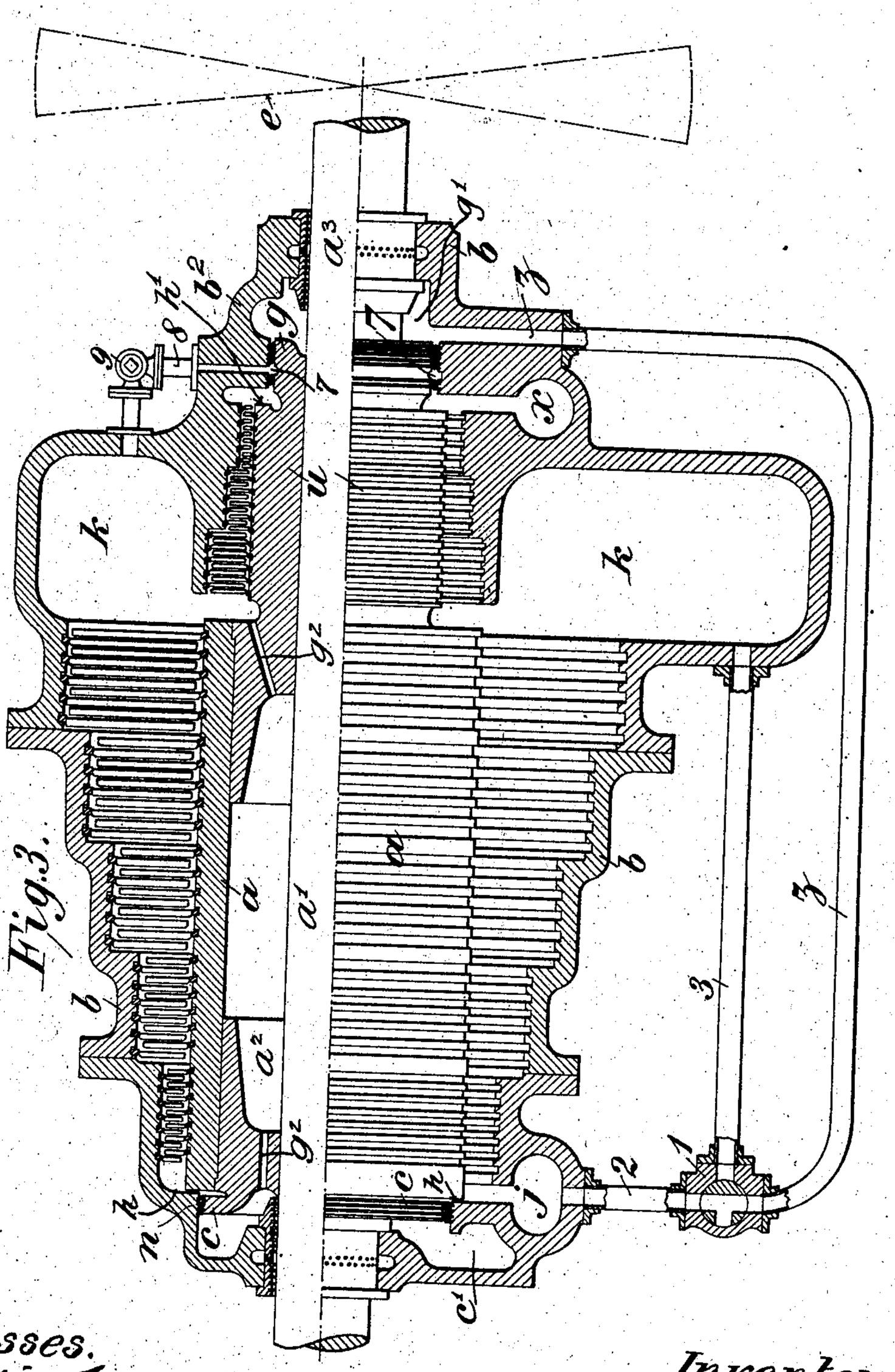

Fig. 3.

Witnesses.
F. Wm Hauck
W. Henry Simms

Inventor.
H. F. Fullagar
by W. Lloyd Wise
Attorney

No. 815,281.

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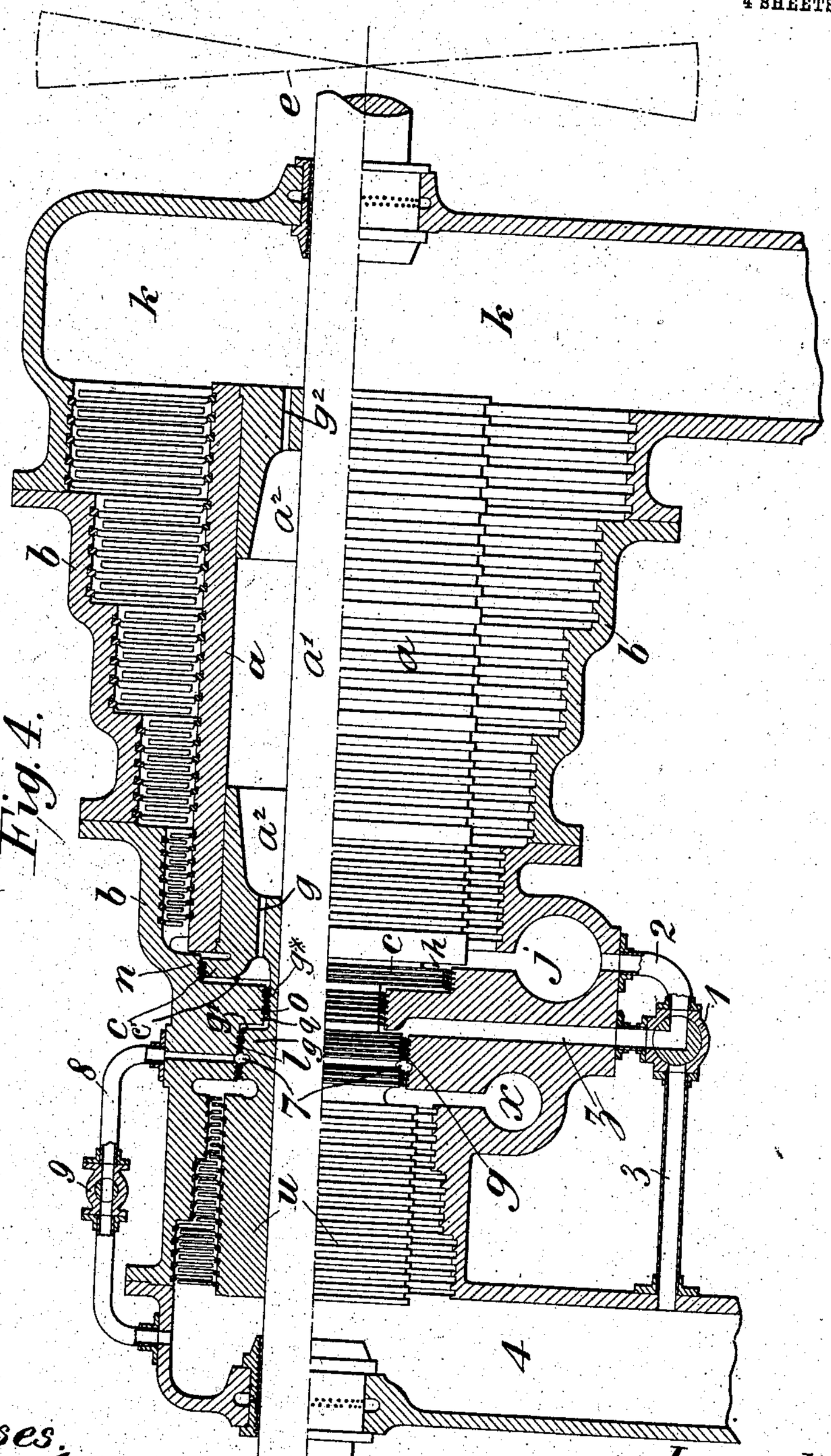
4 SHEETS—SHEET 4.

Fig. 4.



Witnesses.

F. Ulric Koons

W. Henry Simms.

Inventor:

H. F. Fullagar

by W. Lloyd Wise

Attorney

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.

STEAM-TURBINE.

No. 815,281. Specification of Letters Patent. Patented March 13, 1906.

Application filed August 18, 1904. Serial No. 221,255.

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 Steam-Turbines, of which the following is a specification.

In order to avoid the use of a large outer balance-piston in steam-turbines of the kind commonly used for driving dynamos and other machines and having a rotary stepped spindle or drum (hereinafter called a "drum") and balance-pistons designed to counteract the end thrust on the several steps of the drum, I have described in the specification of another application for Letters Patent filed by me on the same day as the present application a construction of turbine wherein the end thrust due to the pressure of steam on the largest step of the drum and the blades carried thereby is counterbalanced by a separate balance-piston that has an effective annular area equal or approximately equal to that of the large balance-piston usually employed for the same purpose and which extends into a steam space or chamber (hereinafter called for distinction a "piston-chamber") that is preferably arranged at the exhaust end of the turbine, the separate balance-piston being made of much smaller diameter than the one for which it is substituted, usually smaller than the large end of the drum, and subjected to the pressure of steam supplied to the said piston-chamber from the steam-space between the last two sets of rotary blades of different diameters and leakage of steam from the piston-chamber to the exhaust-chamber being retarded as far as possible by a packing device of ordinary kind comprising interacting circumferential grooves and projections located between the periphery of the balance-piston and the wall of the piston-chamber.

Now the present invention relates to steam-turbines that are designed for marine use and which usually have a parallel or cylindrical drum and sets of blades of different diameters and a single balance-piston (hereinafter called for distinction the "main piston") that is located at the forward end of the drum and is usually made smaller than would be necessary for correct balance of steam-pressures, so that there may be an end thrust on the drum caused by the steam-pressure and unbalanced thereby in order to counterbalance the end thrust on the drum in the opposite direction due to the action of the propeller driven by the turbine; and the invention has for its object to provide for the balancing of such turbines by means of balance-pistons smaller in diameter than those heretofore employed, the use of large balance-pistons being objectionable for the reasons stated in the aforesaid specification.

For this purpose in a steam-turbine of the kind last referred to the rotary drum is provided according to this invention with a separate balance or auxiliary piston arranged adjacent to a portion thereof of reduced diameter, so as to form an annular surface of the required area upon which steam from the inlet end of the turbine is caused to act in such a way as to counterbalance directly any desired proportion of the end thrust on the drum due to steam-pressure. The provision of this auxiliary piston, which itself is small in diameter, enables the main piston to be made smaller than has hitherto been the case. The auxiliary balance-piston may be arranged on the rear or the forward end of the drum.

For marine purposes two coaxially-arranged turbines are sometimes combined, one of the turbines (hereinafter called for distinction the "main" turbine) being designed for going ahead and the other (hereinafter called for distinction the "reversing-turbine") being designed for going astern. Each turbine-drum is provided with a main piston and packing device, such as described, and each turbine has its own inlet for steam, so that upon admitting steam to the inlet of the main turbine this turbine will rotate the corresponding propeller in a direction for going ahead. the drum of the reversing-turbine being simultaneously rotated in the same direction, and upon cutting off the supply of steam to the main turbine and admitting it to the reversing-turbine the latter, as well as the propeller, will be rotated in the reverse direction for going astern, the drum of the main turbine rotating in the same direction. Steam leaking past the packing device surrounding each main piston is usually led to

the exhaust through the corresponding turbine-drum.

In combined turbines for the purposes mentioned according to this invention the main piston at the rear end of the reversing-turbine has substituted for it an auxiliary balance-piston which is preferably of the same diameter and the rear end of which has an annular surface upon which steam supplied through a separate pipe acts in such a manner as to tend to press the auxiliary balance-piston and turbine-drums in a forward direction when the main turbine is in use, and thereby partly counterbalance the steam-pressure on the drum and rotary blades of that turbine, steam leaking past the packing device of such auxiliary balance-piston being suitably led, preferably as hereinafter described, to the exhaust. Steam leaking past the packing device of the main balance-piston of the main-turbine drum may flow to the exhaust through the drum, as before.

By the use of an auxiliary balance-piston in the manner hereinbefore described the main balance-piston can be made much smaller than would otherwise be necessary, which, as will be readily understood, is a matter of considerable practical importance.

The carrying out of the invention is illustrated in the accompanying drawings, of which Figures 1 to 4, inclusive, represent, partly in longitudinal section and partly in elevation, sufficient for the purpose of four examples of turbines constructed according to this invention.

In each of the examples illustrated in Figs. 1 and 2 the rotary turbine drum or spindle comprises a hollow outer cylindrical portion a, a central portion a', formed by a shaft, and intermediate annular end portions or carriers a^2, these parts being rigidly connected together so as to form a hollow drum, hereinafter sometimes called the "drum a," that is supported by the smaller or reduced end portions a^3 a^4 of the central portion a' within the turbine-casing b, the drum and casing carrying, respectively, sets of rotary and stationary blades a^* and b^* of different diameters. In some cases the parts a a' a^2 of the drum may be made in one piece. c is the main balance-piston, arranged on the forward end of the drum and within a chamber c' in the adjacent portion b' of the casing b, and e is a propeller fixed upon a shaft secured to the rear end of the turbine-shaft a'.

In the example shown in Fig. 1 the drum a is provided at its rear end with an auxiliary balance-piston g, arranged in a chamber g', that extends around the reduced portion a^3 of the drum a and is formed in the adjacent portion b^2 of the casing b. The rear end of the chamber g' is in communication, through the piston g, holes g^2 in the intermediate portions a^2 of the drum, the interior of the outer portion a of the drum, and an annular slit g^3 between the forward intermediate portion a^2 and the piston c, with the steam-inlet j of the turbine, so that live steam will enter the chamber g', where it will press upon the rear end of the piston g and tend to move the piston g and the drum a forward in opposition to the force of the steam acting on the front annular end portion h of the drum, that extends outward beyond the periphery of the main piston c, and on the rotary blades a^*, the escape of steam from the forward end of the piston g to the exhaust-chamber k of the drum a being retarded by a packing device l, such as hereinbefore referred to, arranged between the piston g and the surrounding portion b^3 of the casing b. m is a passage for conveying to the exhaust-chamber k steam that has leaked into the chamber c' past the packing device n of the piston c.

In the example shown in Fig. 2 the auxiliary balance-piston g is arranged on the reduced forward portion a^4 of the turbine-drum and in front of the main piston c. Between the pistons c and g there is an intervening stationary wall or division o, that surrounds the reduced portion a^4 of the drum and is provided with a packing device q or a gland arranged between it and a longitudinal extension g^* of the auxiliary balance-piston g. For supplying steam from the inlet j to act on the rear end of the piston g the inlet j has a branch passage s, leading to the space between the rear end of the piston g and the wall o, and between the forward end of the chamber g' of the piston g and the exhaust-chamber k there is a passage t for leading away the steam that escapes peripherally of the piston g past the packing device l. Steam leaking past the packing device n of the main piston c is led back through that piston and the turbine-drum a to the exhaust-chamber k.

When either of the turbines shown in Figs. 1 and 2 is in operation, the forces tending to move the drum a rearwardly in its casing b are the end thrust, due to the action of the steam on the blades, and the pressure of the steam on an annular portion h of the drum of a radial width equal to the difference between the radii of the outer portion a of the drum and of the main balance-piston c, while the forces which tend to move the drum a in the other direction and which should balance the former forces are the forward thrust, due to the action of the propeller upon the water, and the pressure of the steam on the rear end of the auxiliary balance-piston g.

Figs. 3 and 4 show two examples of combined turbines constructed according to this invention. In each case a a' a^2 is a bladed drum constructed as hereinbefore described for going ahead, and u is a bladed drum fixed to and coaxial with the drum a and adapted for going astern. The drums a and u have balance-pistons c and g, respectively, each

provided with a packing device *n* or *l* of the kind hereinbefore referred to, the piston *g* being adapted to act as an auxiliary balance-piston to the main piston *c*. *j* is the steam-inlet of the main turbine, and *x* is the steam-inlet of the reversing-turbine. The balance-piston *c* and the drum *a* are made hollow, as before, so that the steam that leaks past the piston *c* can escape therethrough to the exhaust-chamber *k*, which is common to the two turbine-drums. The casing *b* in each case is provided with a passage *z* for conducting live steam into the chamber *g'*, formed by the piston *g* and the adjacent portion b^2 of the casing *b*, and wherein the steam will tend to press the auxiliary piston *g* and the two turbine-drums in a forward direction when the main turbine is in use, so as to counteract partly the rearward end thrust of the steam on the forward end portion *h* of the drum *a* and its rotary blades.

In the example shown in Fig. 3 the reversing-drum *u* is at the rear of the main drum *a*, and the auxiliary balance-piston *g* is arranged at the rear of the drum *u* and on the reduced end portion a^3 of the drum formed by the shaft *a'*. The passage *z* leads from the rear end of the chamber *g'* of the piston *g* to a three-way valve 1, which is in communication through a passage 2 with the steam-inlet *j* of the main turbine and through a passage 3 with the exhaust-chamber *k*, so that when the drum *a* is to be used the steam-inlet *j* can by means of the valve 1 be placed in communication with the passage *z*, and when the drum *u* is to be used the passage *z* can by means of the valve 1 be placed in communication with the exhaust-chamber *k* through passage 3 and also into communication with steam-inlet *j* through passage 2. This may be accomplished by rotating the valve 1 one hundred eighty degrees. The steam is of course cut off from steam-inlet *j* and admitted to inlet *x* of the reversing-drum *u*. Under these conditions both ends of the drum *a* are in communication with the exhaust, and the drum *a* cannot by any possibility operate to compress fluid into its inlet *j*, and thus retard the operation of the reversing-drum in developing power for running astern.

In the modified example shown in Fig. 4 the reversing-turbine drum *u* and its auxiliary balance-piston *g* are arranged in front of the main turbine-drum *a* and have between them and the piston *c* a portion *g** of the drum of smaller diameter and around that portion a stationary wall or division *o*, provided with a packing device *q'*. The steam-inlet *j* of the main turbine leads to the forward end of the drum *a*, and the steam-inlet *x* of the reversing-turbine leads to the rear end of the drum *u*. The chamber *g'*, formed between the rear end of the piston *g*, the casing *b*, and the wall *o*, is connected by the passage *z* with a three-way valve 1, adapted to place it in communication by means of a passage 2 with the steam-inlet *j* of the main turbine or by means of the passage 3 with the exhaust-chamber 4 of the reversing-turbine.

In each of the examples shown in Figs. 3 and 4 in order to prevent steam that has leaked past the packing device *l* of the auxiliary balance-piston *g* from the passage *z* and chamber *g'* from acting upon the blades of the reversing-drum *u* and retarding the motion of the main turbine the outer periphery of the piston *g* is formed at a part thereof near to the steam-inlet *x* of the drum *u* with an annular groove 7, which is always in communication with a pipe 8, provided with a valve 9, by means of which the annular chamber formed by the groove 7 and the surrounding part of the casing *b* can be placed into communication with the exhaust-chamber *k*, Fig. 3, or 4, Fig. 4, when the main turbine is to be used. The portion of the packing device *l* between the annular groove 7 and the rear end of the drum *u* is sufficient in axial length to prevent steam that has reached the groove 7 from passing forward to the drum *u* when the valve 9 is open. When the reversing-turbine is to be used, the valve 9 is closed in order that the entire length of the packing device between the steam-inlet *x* and the chamber *g'* may be employed for retarding the escape of steam.

The valve 9 may in each case be connected with the valve 1, so as to be automatically opened and closed on the corresponding operation of the latter valve.

Steam leaking past the packing device *n* of the main piston *c* may in each case and, as shown in Figs. 3 and 4, conveniently be led to the exhaust-chamber *k* through the said main piston and the drum *a*.

The operation in the case of the turbines shown in Figs. 3 and 4 is as follows: When the propeller *e* is being driven by the drum *a* for going ahead, steam is admitted at *j*, acts upon the blades of the drum *a*, and passes thence into the exhaust-chamber *k*, and steam also admitted at *j* presses against the forward end portion *h* of the drum *a*, any steam escaping past the packing *n* going to the exhaust-chamber *k* through the piston *c* and the drum *a*. Steam from the inlet *j* also passes through the pipe 2, the cock 1, and the passage *z* to the rear end of the piston *g*, against which it presses, any steam escaping past the packing *l* of the piston *g* into the annular space 7 passing thence into the exhaust-chamber *k*, Fig. 3, or 4, Fig. 4, through the pipe 8 and the cock 9, and so avoiding acting upon the blades of the drum *u*. In the turbine shown in Fig. 4 steam is prevented from escaping from the chamber *g'* of the piston *g* to the forward end of the chamber *c'* of piston *c*, and so to the exhaust-chamber *k*, by the packing *l* of the partition *o*. The forces tend-

ing to move the drums *a* and *u* in their casing *b* are as stated in reference to the drum *a* of Figs. 1 and 2.

When the propeller *e* is being driven by the drum *u* for going astern, steam is admitted at *x*, acts upon the blades of the drum *u*, and passes thence into the exhaust-chamber *k*, Fig. 3, or 4, Fig. 4, while the escape of steam from the rear end of the drum *u* past the piston *g* into the passage *z*, and thence through the pipe 3 (which is in this case in communication with the passage *z* through the cock 1) into the chamber *k*, Fig. 3, or 4, Fig. 4, is retarded by the packing device *l*, the cock 9 being then closed. The forces tending to move the drums *a* and *u* forwardly in their casing *b* are the end thrust, due to the action of the steam on the blades of the drum *u*, and the pressure of steam on an annular portion *h'* of the drum *u* of a radial width equal to the difference between the radii of the drum *u* and the piston *g*, while the force that tends to move the drum *a* in the other direction is the rearward thrust due to the action of the propeller upon the water.

What I claim is—

1. A steam-turbine comprising a bladed drum, a piston fast to said drum and located at the inlet end thereof and less in diameter than said end, means for peripherally of said piston retarding the escape of steam between said piston and the turbine-casing in a direction away from said drum and for causing said steam to exert upon said drum a resultant end thrust in the direction opposite to the aforesaid direction, a second piston, and means for peripherally of said second piston retarding the escape of steam between said second piston and said casing and for causing the last-mentioned steam to produce on said second piston an end thrust in the direction opposite to that of the first-mentioned end thrust.

2. A steam-turbine comprising a bladed drum, a piston fast to said drum and located at the inlet end of said drum and in contact with and less in diameter than said end, means for peripherally of said piston retarding the escape of steam between said piston and the turbine-casing in a direction away from said drum and for causing said steam to exert upon said drum a resultant end thrust in the direction opposite to the aforesaid direction, a second piston, and means for peripherally of said second piston retarding the escape of steam between said second piston and said casing and for causing the last-mentioned steam to produce on said second piston an end thrust in the direction opposite to that of the first-mentioned end thrust.

3. A steam-turbine comprising a bladed drum, a piston fast to said drum and located at the inlet end of said drum and less in diameter than said end, means for peripherally of said piston retarding the escape of steam between said piston and the turbine-casing in a direction away from said drum and for causing said steam to exert upon said drum a resultant end thrust in the direction opposite to the aforesaid direction, a second piston, means for peripherally of said second piston retarding the escape of steam between said second piston and said casing and for causing the last-mentioned steam to produce on said second piston an end thrust in the direction opposite to that of the first-mentioned end thrust, and means for leading to exhaust steam that will have escaped past the said two pistons in the directions indicated.

4. A steam-turbine comprising a bladed drum, a piston fast to said drum and located at the inlet end of said drum and less in diameter than said end, means for peripherally of said piston retarding the escape of steam between said piston and the turbine-casing in a direction away from said drum and for causing said steam to exert upon said drum a resultant end thrust in the direction opposite to the aforesaid direction, a second drum adapted by blading for rotation in the direction opposite to that for which the first-mentioned drum is bladed, a second piston fast to said second drum and located at the inlet end thereof, and means for peripherally of said second piston retarding the escape of steam between said second piston and said casing and for causing the last-mentioned steam to produce on said second piston an end thrust in the direction opposite to that of the first-mentioned end thrust.

5. A steam-turbine comprising a bladed drum, a piston fast to said drum and located at the inlet end of said drum and in contact with and less in diameter than said end, means for peripherally of said piston retarding the escape of steam between said piston and the turbine-casing in a direction away from said drum and for causing said steam to exert upon said drum a resultant end thrust in the direction opposite to the aforesaid direction, a second drum adapted by blading for rotation in the direction opposite to that for which the first-mentioned drum is bladed, a second piston fast to said second drum and located at the inlet end thereof, and means for peripherally of said second piston retarding the escape of steam between said second piston and said casing and for causing the last-mentioned steam to produce on said second piston an end thrust in the direction opposite to that of the first-mentioned end thrust.

6. A steam-turbine comprising a bladed drum, a piston fast to said drum and located at the inlet end of said drum and less in diameter than said end, means for peripherally of said piston retarding the escape of steam between said piston and the turbine-casing in a direction away from said drum and for causing said steam to exert upon said drum a re-

sultant end thrust in the direction opposite to the aforesaid direction, a second drum adapted by blading for rotation in the direction opposite to tnat for which the first-mentioned drum is bladed, a second piston fast to said second drum and in contact with and located at the inlet end thereof, and means for peripherally of said second piston retarding the escape of steam between said second piston and said casing and for causing the last-mentioned steam to produce on said second piston an end thrust in the direction opposite to that of the first-mentioned end thrust.

7. A steam-turbine comprising a bladed drum, a piston fast to said drum and located at the inlet end of said drum and less in diameter than said end, means for peripherally of said piston retarding the escape of steam between said piston and the turbine-casing in a direction away from said drum and for causing said steam to exert upon said drum a resultant end thrust in the direction opposite to the aforesaid direction, a second drum adapted by blading for rotation in the direction opposite to that for which the first-mentioned drum is bladed, a second piston fast to said second drum and located at the inlet end thereof, means for peripherally of said second piston retarding the escape of steam between said second piston and said casing and for causing the last-mentioned steam to produce on said second piston an end thrust in the direction opposite to that of the first-mentioned end thrust, and means for leading to exhaust steam that will have escaped past the said two pistons in the directions indicated.

8. A steam-turbine comprising a bladed drum, a piston fast to said drum and located at the inlet end of said drum and less in diameter than said end, means for peripherally of said piston retarding the escape of steam between said piston and the turbine-casing in a direction away from said drum and for causing said steam to exert upon said drum an end thrust in the direction opposite to the aforesaid direction, a second drum coaxial with and fast to the first-mentioned drum and adapted by blading for rotation in the direction opposite to that for which the first-mentioned drum is bladed, a second piston fast to said second drum and located at the inlet end thereof, means for enabling that end of said second piston which is farther from said second drum to be placed into communication either with the inlet of the first-mentioned drum or with an exhaust-space according as the first-mentioned or the second-mentioned drum is to be used, and means for when said end of said second piston is in communication with said inlet retarding peripherally of said second piston the escape of steam between said second piston and said casing from said end of said second piston and for causing the last-mentioned steam to produce on said second piston an end thrust in the direction opposite to that of the first-mentioned end thrust.

9. A steam-turbine comprising a bladed drum, a piston fast to said drum and located at the inlet end of said drum and in contact with and less in diameter than said end, means for peripherally of said piston retarding the escape of steam between said piston and the turbine-casing in a direction away from said drum and for causing said steam to exert upon said drum an end thrust in the direction opposite to the aforesaid direction, a second drum coaxial with and fast to the first-mentioned drum and adapted by blading for rotation in the direction opposite to that for which the first-mentioned drum is bladed, a second piston fast to said second drum and located at the inlet end thereof, means for enabling that end of said second piston which is farther from said second drum to be placed into communication either with the inlet of the first-mentioned drum or with an exhaust-space according as the first-mentioned or the second-mentioned drum is to be used, and means for when said end of said second piston is in communica tion with said inlet retarding peripherally of said second piston the escape of steam between said second piston and said casing from said end of said second piston and for causing the last-mentioned steam to produce on said second piston an end thrust in the direction opposite to that of the first-mentioned end thrust.

10. A steam-turbine comprising a bladed drum, a piston fast to said drum and located at the inlet end of said drum and less in diameter than said end, means for peripherally of said piston retarding the escape of steam between said piston and the turbine-casing in a direction away from said drum and for causing said steam to exert upon said drum an end thrust in the direction opposite to the aforesaid direction, a second drum coaxial with and fast to the first-mentioned drum and adapted by blading for rotation in the direction opposite to that for which the first-mentioned drum is bladed, a second piston fast to said second drum and in contact with and located at the inlet end thereof, means for enabling that end of said second piston which is farther from said second drum to be placed into communication either with the inlet of the first-mentioned drum or with an exhaust-space according as the first-mentioned or the second-mentioned drum is to be used, and means for when said end of said second piston is in communication with said inlet retarding peripherally of said second piston the escape of steam between said second piston and said casing from said end of said second piston and for causing the last-mentioned steam to produce on said second piston an

end thrust in the direction opposite to that of the first-mentioned end thrust.

11. A steam-turbine, comprising a bladed drum, a piston fast to said drum and located at the inlet end of said drum and less in diameter than said end, means for peripherally of said piston retarding the escape of steam between said piston and the turbine-casing in a direction away from said drum and for causing said steam to exert upon said drum an end thrust in the direction opposite to the aforesaid direction, a second drum coaxial with and fast to the first-mentioned drum and adapted by blading for rotation in the direction opposite to that for which the first-mentioned drum is bladed, a second piston fast to said second drum and located at the inlet end thereof, means for enabling that end of said second piston which is farther from said second drum to be placed into communication either with the inlet of the first-mentioned drum or with an exhaust-space according as the first-mentioned or the second-mentioned drum is to be used, packing means for when said end of said second piston is in communication with said inlet retarding peripherally of said second piston the escape of steam between said second piston and said casing from said end of said second piston, means for causing the last-mentioned steam to produce on said second piston an end thrust in the direction opposite to that of the first-mentioned end thrust, a passage leading from an annular space at the end of said packing means nearer to said second drum to an exhaust-space, a valve adapted to control the flow of steam through said passage, and packing means located between said passage and the other end of said second piston and adapted when said valve is open to prevent steam that has leaked past the first-mentioned packing means from passing to said second drum.

12. A steam-turbine comprising a bladed drum, a piston fast to said drum and located at the inlet end of said drum and less in diameter than said end, means for peripherally of said piston retarding the escape of steam between said piston and the turbine-casing in a direction away from said drum and for causing said steam to exert upon said drum an end thrust in the direction opposite to the aforesaid direction, a second drum coaxial with and fast to the first-mentioned drum and adapted by blading for rotation in the direction opposite to that for which the first-mentioned drum is bladed, a second piston fast to said second drum and located at the inlet end thereof, passages leading from the end of said second piston opposite to said second drum, from the inlet end of the first-mentioned drum, and from an exhaust-space, a three-way valve to which said passages lead and which is adapted to enable said end of said second piston to be placed into communication either with the inlet of the first-mentioned drum or with said exhaust-space according as the first-mentioned or the second-mentioned drum is to be used, and means for when said end of said second piston is in communication with said inlet retarding peripherally of said second piston the escape of steam between said second piston and said casing from said end of said second piston and causing the last-mentioned steam to produce on said second piston an end thrust in the direction opposite to that of the first-mentioned end thrust.

13. A steam-turbine comprising a bladed drum, a piston fast to said drum and located at the inlet end thereof and less in diameter than said end, means for retarding peripherally of said piston the escape of steam between said piston and the turbine-casing in a direction away from said drum and for causing said steam to exert upon said drum an end thrust in the direction opposite to the aforesaid direction, a second drum coaxial with, fast to, and having its exhaust end adjacent to the exhaust end of the aforesaid drum and adapted by blading for rotation in the direction opposite to that for which the first-mentioned drum is bladed, a second piston fast to said second drum and located at the inlet end thereof, means for enabling that end of said second piston which is farther from said second drum to be placed into communication either with the inlet of the first-mentioned drum or with an exhaust-space according as the first-mentioned or the second-mentioned drum is to be used, and means for when said end of said second piston is in communication with said inlet retarding peripherally of said second piston the escape of steam between said second piston and said casing from said end of said second piston and causing the last-mentioned steam to produce on said second piston an end thrust in the direction opposite to that of the first-mentioned end thrust.

14. A steam-turbine comprising a bladed drum, a piston fast to said drum and located at the inlet end thereof and less in diameter than said end, means for retarding peripherally of said piston the escape of steam between said piston and the turbine-casing in a direction away from said drum and for causing said steam to exert upon said drum an end thrust in the direction opposite to the aforesaid direction, said piston and drum being adapted to allow steam that has escaped past said means to pass through them into the exhaust-space of said drum, a second drum coaxial with, fast to, and having its exhaust end adjacent to the exhaust end of the aforesaid drum and adapted by blading for rotation in the direction opposite to that for which the first-mentioned drum is bladed, a second piston fast to said second drum and located at the inlet end thereof, means for enabling that end of said second piston which

is farther from said second drum to be placed into communication either with the inlet of the first-mentioned drum or with an exhaust-space according as the first-mentioned or the second-mentioned drum is to be used, said second piston and second drum being closed to the passage through them of steam that has escaped past the second piston to the end thereof farther from said second drum, and means for when said end of said second piston is in communication with said inlet retarding peripherally of said second piston the escape of steam between said second piston and said casing from said end of said second piston and causing the last-mentioned steam to produce on said second piston an end thrust in the direction opposite to that of the first-mentioned end thrust.

15. A reversible turbine comprising a plurality of opposed sets of blades, and controllable means for placing both ends of a set of blades not developing power in communication with the exhaust.

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

HUGH FRANCIS FULLAGAR.

Witnesses:—

CHARLES EDGAR GROUNSELL,

JAMES ROUTLEDGE.