Sept. 15, 1931. R. C. ALLEN 1,823,310

ELASTIC FLUID TURBINE

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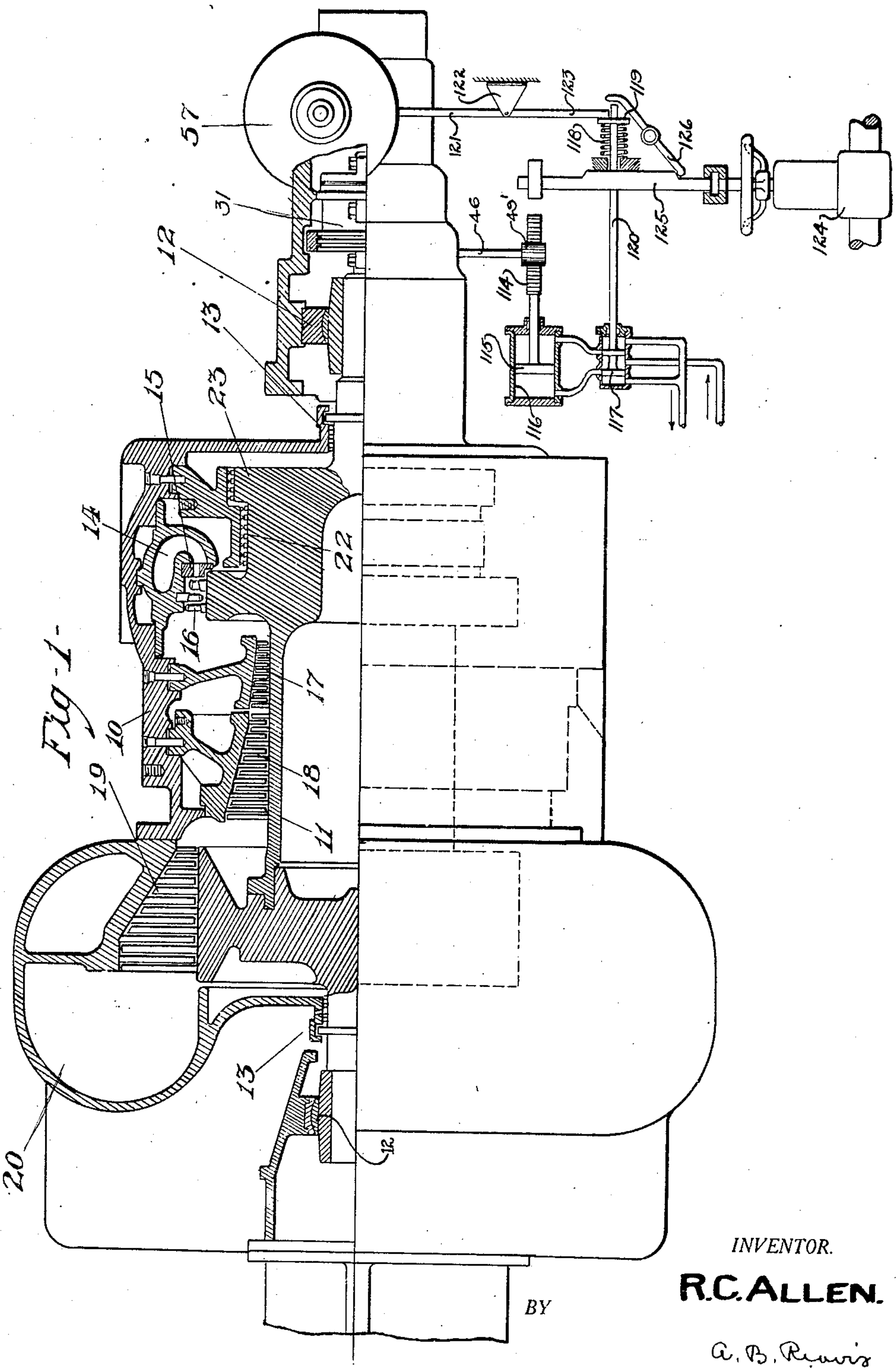

INVENTOR.

R.C. ALLEN.

BY

A. B. Reavis

ATTORNEYS.

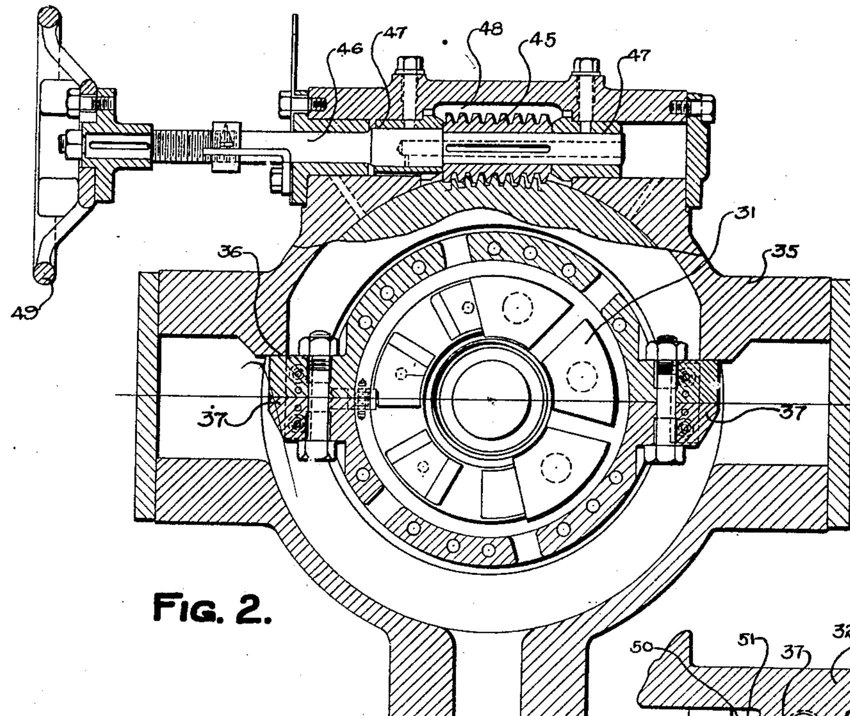

FIG. 2.

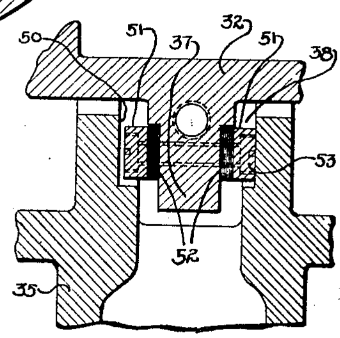

FIG. 4.

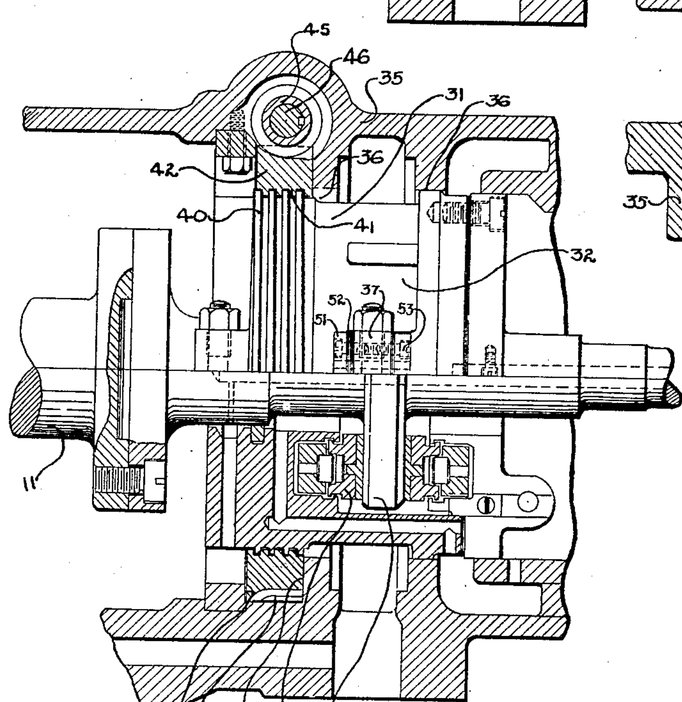

FIG. 3.

INVENTOR
R.C. ALLEN.
BY
a. B. Reavis
ATTORNEY

Sept. 15, 1931. R. C. ALLEN 1,823,310

ELASTIC FLUID TURBINE

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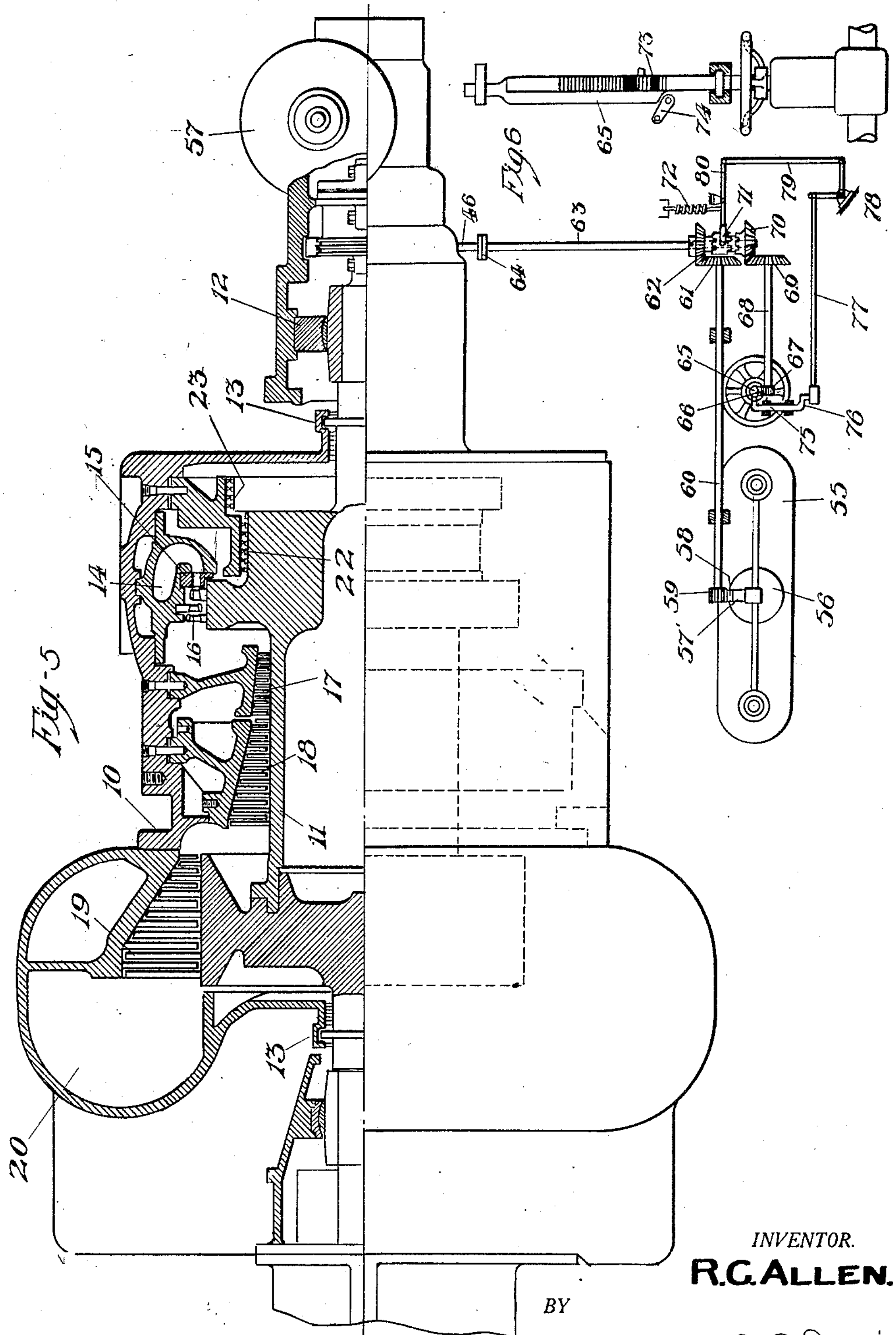

INVENTOR.

R.G.ALLEN.

BY

A. B. Reavis

ATTORNEYS.

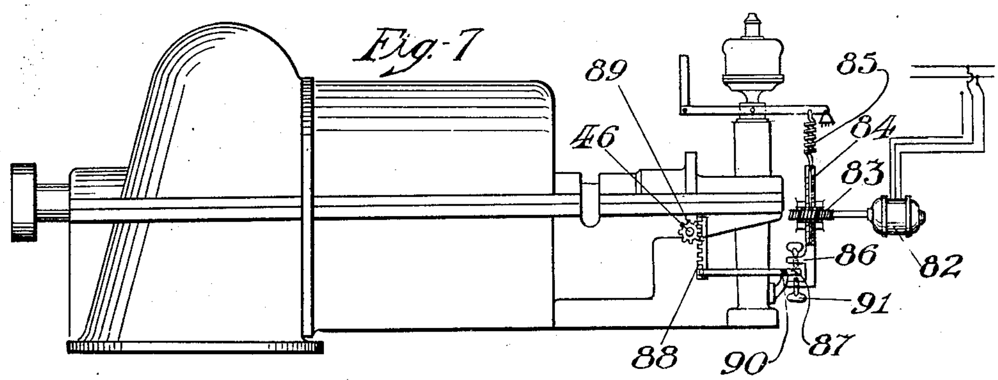

Fig-7

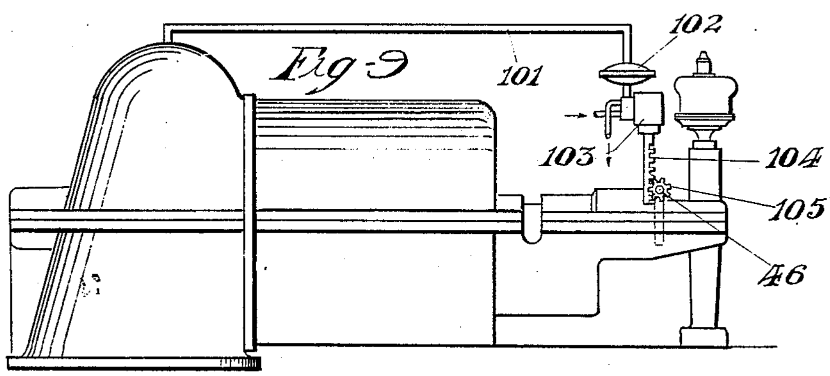

Fig-9

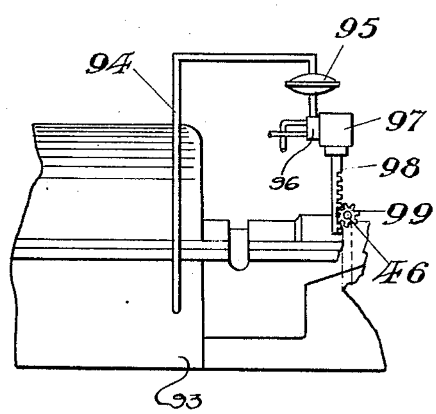

Fig 8

INVENTOR.
R.C. ALLEN.

BY

A. B. Reavis
ATTORNEYS.

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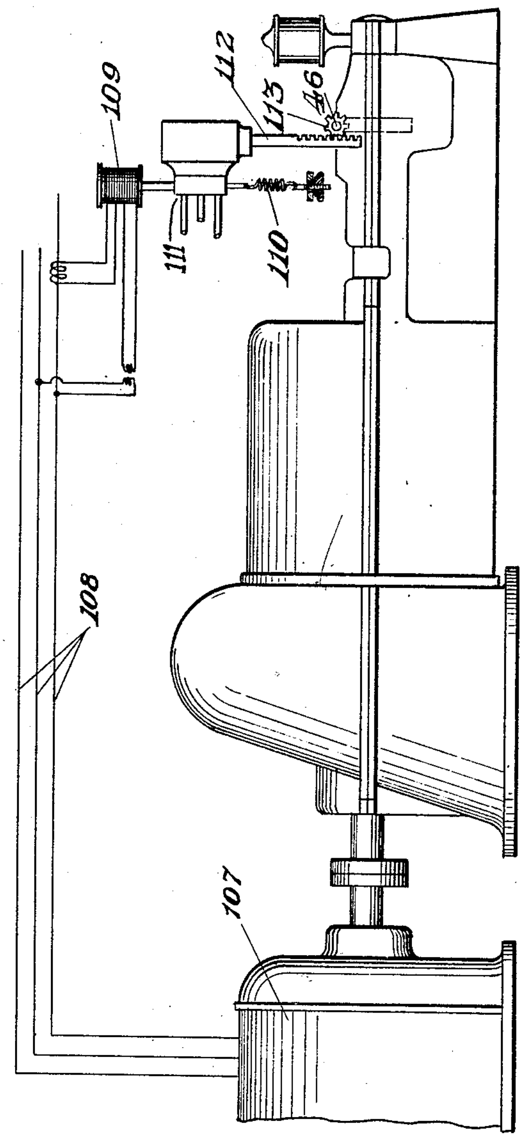
Fig-10



INVENTOR.

R.C. ALLEN.

BY

A. B. Rivers

ATTORNEYS.

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Fig-11

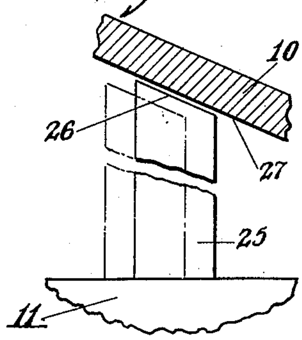


Fig-12

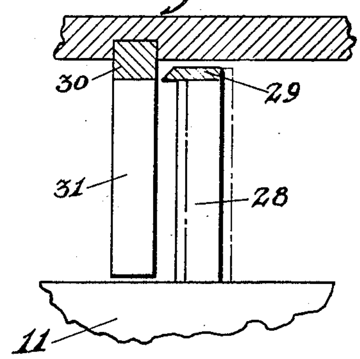


Fig-13

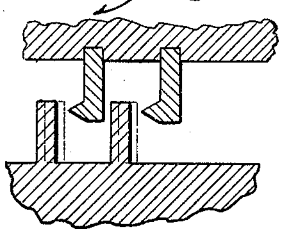


Fig-14

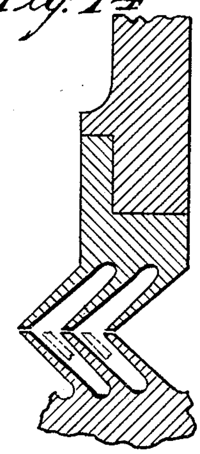


Fig-15

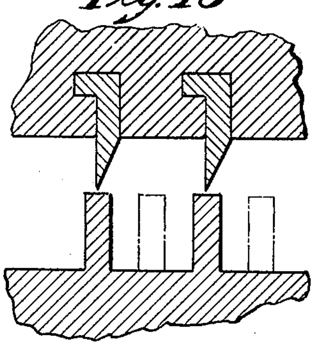
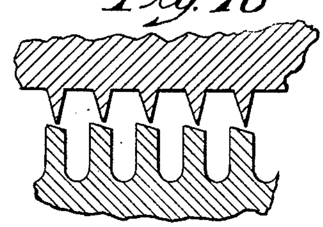


Fig-16



INVENTOR.

R.C.ALLEN.

BY

A. B. Ruwis

ATTORNEYS.

Patented Sept. 15, 1931 1,823,310

UNITED STATES PATENT OFFICE

ROBERT C. ALLEN, OF SWARTHMORE, PENNSYLVANIA, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA

ELASTIC FLUID TURBINE

Application filed May 23, 1929. Serial No. 365,483.

My invention relates to elastic fluid turbines, more particularly to that type employing packing elements normally defining fine clearances, but which may be disposed to provide large clearances upon axial movement of the rotor, and it has for an object to provide apparatus of this character wherein the packing elements may have greater durability under varied conditions of operation.

On account of distortion, expansion and contraction effects, or warping, usually taking place when a turbine is started or is operating under reduced or no load conditions, it is desirable to increase the clearances in order to avoid rubbing or injury to the packing elements. On the other hand, when operating under full load conditions, it is desirable that the clearances shall be reduced to a minimum in order to avoid the leakage of steam. Accordingly, therefore, it is a more particular object of my invention to provide a turbine of this character with means for shifting the rotor axially in order that the packing elements may define large clearances under reduced load or starting and stopping conditions and small clearances when operating normally.

While I may provide manual means for shifting the turbine rotor axially for the purposes stated, I prefer to do this automatically to remove the responsibility from the operator. Accordingly, therefore, it is a more particular object of my invention to provide for shifting of the turbine rotor for the purposes stated by means responsive to the load conditions.

These and other objects are effected by my invention, as will be apparent from the following description and claims taken in connection with the accompanying drawings, forming a part of this application, in which:

Fig. 1 is a longitudinal sectional view of a turbine having my improvement applied thereto;

Fig. 2 is a detail view showing a portion of the operating mechanism in section;

Fig. 3 is a sectional view showing the thrust bearing;

Fig. 4 is a detail view, shown partly in section, of motion-limiting means for the rotor;

Fig. 5 is a longitudinal sectional view of a turbine, similar to Fig. 1, but showing another form of automatic mechanism for controlling axial shifting of the rotor;

Fig. 6 is a detail view of a portion of the automatic operating mechanism employed in Fig. 5;

Fig. 7 shows a turbine in side elevation with automatic mechanism controlling shifting of the rotor in response to operation of the speed changer;

Fig. 8 is a fragmentary view of a turbine showing the automatic mechanism responsive to inlet steam pressure;

Fig. 9 is a view similar to Fig. 7 but showing the automatic mechanism responsive to pressure existing in the exhaust chamber;

Fig. 10 is a view similar to Fig. 7 and showing the automatic mechanism responsive to load conditions of the generator driven by the turbine;

Fig. 11 is a detail view of one type of turbine blade;

Fig. 12 is a detail view of an end-tightened turbine blade;

Fig. 13 is a detail view of packing of the end-tightened type which may be used in connection with dummy pistons, diaphragms, or with glands; and,

Figs. 14, 15 and 16 are detail views of packing of the radial type which may be disposed to provide large clearances.

Referring now to the drawings more in detail, in Fig. 1, I show a turbine including a housing or cylinder construction 10 and a rotor 11, the rotor being supported in proper relation with respect to the housing construction by suitable bearings 12. Glands 13 are arranged between the ends of the casing and the rotor or spindle 11. As shown, steam or elastic fluid enters the chamber 14 from any suitable valve mechanism (not shown), the steam undergoes pressure-velocity conversion in the nozzles 15, and the high velocity steam has velocity energy abstracted therefrom preferably in the velocity compounded stage, at 16. Thereafter, the steam preferably undergoes fractional expansion in the blading shown at 17, 18 and 19, and steam leaving the last row of such blading enters the exhaust chamber 20 from which it passes to a condenser (not shown). While I have referred to turbine blading or stages at 16, 17, 18 and 19, it is to be understood that, so far as my invention is concerned, any form or arrangement of blading may be used so long as the principles of my invention may be advantageously utilized.

The blading 17, 18 and 19 may be of the reaction type, in which case it is necessary to employ a dummy piston or pistons indicated at 22 and 23 for counterbalancing the differences in pressure existing between the admission and exhaust ends of the reaction blading. In accordance with my invention, I prefer to have dummy pistons of such size and arrangement as to counterbalance substantially all of the end thrust created by the differences in steam pressure existing between the admission and exhaust ends of the reaction turbine blading.

With the form of turbine shown in Fig. 1, the glands 13, the dummy pistons 22 and 23, and some of the blading 17, 18 and 19 are so arranged that, in one endwise position of the rotor, small clearances are defined and, in another endwise position thereof, larger clearances are defined.

With respect to the turbine blading providing variable clearance, reference is made to Figs. 11 and 12 showing two types. In Fig. 11, the moving blades 25 carried by the rotor 11 have their tips inclined, as indicated at 26, to cooperate with the interior inclined surface of the housing or casing construction 10. With the blade 25 in full line position, minimum clearance is defined between its tip 26 and the interior inclined surface 27 of the casing construction 10; and, if the rotor is shifted to the dotted line position, larger clearance is defined.

With the end-tightened form of blading shown in Fig. 12, the moving blades 28 carried by the rotor 11 are provided with sharp-edged shrouds 29 which cooperate laterally with any suitable structure, for example, the root portion structure 30 of the fixed blades 31, the shrouds 29 and the root portion 30 constituting end-tightened packing to define small clearance to avoid tip leakage. The rotor with this type of blading is shiftable to define small and large clearances.

Fig. 13 shows end-tightened packing suitable for the glands and dummies and capable, depending upon longitudinal adjustment of the rotor, of defining large and small clearances.

Figs. 14, 15 and 16 show three forms of radial packing elements, wherein, upon longitudinal movement of the rotor to the dotted line position shown in Figs. 14 and 15, the packing elements are disposed out of registry, thereby providing large safe clearances.

At times, particularly when stopping and starting up, due to expansion and contraction effects, to warping, or possibly to a certain amount of mechanical unbalance, there is likelihood of the packing elements rubbing or being injured if the clearances are too small. On the other hand, when operating under normal full load conditions, the clearances should be reduced as much as practicable to minimize leakage. In Fig. 1, I show apparatus for shifting the rotor axially so that the packing elements may define large and small clearances when required. When shutting down the turbine or when starting, the operator should adjust the turbine rotor so that the packing elements define minimum clearances; and, after reaching full power conditions, the rotor should be shifted axially in order to reduce the clearances.

In Fig. 1, I show a thrust bearing 31 connected so as to move axially with the rotor. Upon reference to Fig. 3, it will be noted that the thrust bearing consists of a housing 32 arranged to enclose thrust bearing segments 33 cooperating with opposed sides of the thrust collar 34 carried by the rotor shaft 11. The thrust bearing is movable axially with respect to the housing structure 35, any suitable guide bearing means, as indicated at 36, being provided. The thrust bearing is also guided by the housing construction 35 due to projections 37 engaging in recesses 38 provided by the housing construction; however, the recesses 38 and the projections 37 perform other functions, namely, they prevent the thrust bearing from turning with respect to the housing structure 35 and the projections 37 coperate with either abutment surface for the purpose of limiting the axial movement of the turbine rotor.

If the thrust bearing housing is moved axially, the turbine rotor will be similarly moved. Accordingly, means is provided for shifting the thrust bearing and the turbine rotor so that the packing elements carried by the rotor may occupy either a position defining minimum clearances or a position defining maximum clearances. To this end, the thrust bearing housing is provided with an external thread 40 arranged to engage the internal thread 41 of a worm gear ring 42, the latter ring being arranged in a recess 43 provided in the housing construction 35 and being prevented from axial movement by lateral abutments 44 constituting walls of the annular recess 43. The gear ring 42 meshes with a worm 45 carried by the shaft 46, the latter being carried by bearings 47 secured in place with respect to the housing construction 35, which is extended laterally in order to provide a chamber 48 for the worm and to provide material for supporting the bearings 47.

The shaft 46 extends outwardly from the housing construction 35 and is connected to any suitable device for operating the same. As shown in Fig. 2, an operating hand wheel 49 is secured to the outer end of the shaft 46.

From the structure described, it will be apparent that if the turbine rotor occupies a position such that the packing elements define minimum clearances, it may be shifted to define larger clearances by operation of the hand wheel 49, the latter operating through the worm gear 42 and the threads 40 and 41 to secure shifting of the thrust bearing and therefore of the rotor.

Movement of the rotor in either direction is limited by suitable abutment means. Referring to Figs. 2, 3 and 4, the projections 37, already referred to, cooperate with abutment surfaces 50 provided in the recesses 38 to limit axial movement of the thrust bearing and of the rotor, the projections 37 preferably being provided with spacing means so that the clearance existing with respect to the end walls of the recesses 38 may be suitably varied to secure an accurate range of movement. To this end, each side of each projection 37 is provided with abutment blocks 51 spaced from the projection 37 by shims 52, the blocks and shims being secured to the projections in any suitable manner, as by the screws 53. After suitably adjusting the abutment blocks with respect to the abutment surfaces 50, the rotor may be shifted so that its packing elements define either minimum or maximum clearances merely by operating the hand wheel 49 until the abutment means prevents further operation, at which time the rotor will be either in the position for minimum clearances or in the position for maximum clearances. When shutting down the turbine or when starting up, the operator will adjust the turbine rotor for maximum clearances so as to avoid the possibility of injury to the packing elements due to irregular expansion and contraction effects, to warping, or possibly to effects of unbalance brought about due to temperature changes. After the turbine is operating under full load, the operator may then shift the rotor axially until limited by the abutment means, whereupon the packing elements will be in a position defining minimum clearances.

The thrust bearing housing is preferably moved automatically in accordance with some load condition of the turbine, by suitable mechanism such as shown in Fig. 1. This mechanism is controlled in accordance with the admission of steam to the turbine.

A pinion 49′ is secured to the end of the shaft 46 and meshes with a rack 114, the latter being connected to a piston 115 operating in a cylinder 116. The mechanism is arranged so that when the rack 114 is moved to the right, the thrust bearing housing moves the rotor to provide maximum packing clearances, and when the rack is moved to the left minimum packing clearances are provided.

Fluid pressure is supplied to the cylinder 116 for actuating the piston 115 and is controlled by a suitable pilot valve 117. When the pilot valve is moved to the right of the position shown on the drawings, fluid pressure is applied to the piston 115 to move the rack 114 toward the left, and when the pilot valve is moved to the left of the position shown, fluid pressure moves the piston 115 and the rack 114 to the right. The pilot valve 117 has a stem 120, which is biased to the right by a spring 118 acting on a collar 119 on the stem.

At 121 is shown a lever connected to a stationary fulcrum 122. One end of the lever is connected to the governing mechanism 57 and the other end, at 123, is adapted to bear against the collar 119 to move the valve 117. The lever 121 is so arranged with respect to the governing mechanism that the valve 117 is moved to the right of the position shown when the governing mechanism admits steam for carrying load, and to the left when the admission is reduced to substantially no load condition.

At 124 is shown a throttle valve which is also adapted to cut off the supply of motive fluid to the turbine. A cam member 125 is attached to the throttle valve, and is designed, upon closing movement of the throttle valve, to rotate a lever 126 in counter-clockwise direction. The other end of the lever 126 is adapted to contact the free end of the rod 120 and to move the pilot valve 117 to the left.

The operation of this mechanism will be readily apparent. When the admission of motive fluid is such as to carry no load, the pilot valve 117 is moved to the left by the lever 121 and the rack 114 is moved to the right, whereupon the thrust bearing housing moves the rotor to provide maximum clearances. When, however, the governing mechanism provides increased fluid admission for carrying load, the free end 123 of the lever 121 moves to the right and the spring 118 acting on the collar 119 moves the pilot valve 117 to the right. The rack 114 is thereupon moved to the left and the thrust bearing housing moves the rotor to the position of minimum packing clearances.

During such movements of the governing mechanism, the throttle valve is normally fully open. However, should the throttle valve be closed, the lever 126 is rotated counter-clockwise to move the pilot valve 117 to the left, thereby operating the mechanism to provide maximum clearances.

In Fig. 5, I show another form of means for shifting the rotor axially in an automatic manner due to the direct mechanical connection with the main governor valve indicated at 55, this valve having associated therewith a suitable operating cylinder 56 which is operated in response to the governor 57 of the turbine. When the turbine is operating under no load or light load, the rotor should be adjusted for large clearances. Therefore, I provide means associated with the governor mechanism to effect automatic operation of the shaft 46 and therefore shifting of the turbine rotor. In order to accomplish this effect, I show the operating cylinder 56 of the governor system having an extension or rod 57′ provided with a rack 58 meshing with a pinion 59 carried by a shaft 60, the shaft 60 being connected by bevel gears 61 and 62 to a shaft 63 coupled at 64 to the operating shaft 46. With this arrangement, upon a decrease in load to no load or light load, the operating piston of the operating cylinder will be correspondingly moved and the extension connected thereto will operate the train of mechanism for shifting the turbine rotor to the large clearance position. It is to be understood that any suitable mechanism may be employed to achieve this result and that the system of gearing and shafts illustrated is merely one example of mechanism which may be employed for this purpose.

In shutting down a turbine, the load is first removed. The governor valve then operates to restrict the admission of steam to prevent the turbine from running away. The next operation is o close the throttle valve and this results in the machine slowing down; however, if the steam is shut off, the governor valve opens due to the reduction in speed. It is, therefore, desirable to have mechanism operable to shift the rotor or spindle to large clearance position when the throttle valve is closed. Mechanism for the achievement of this purpose may assume various forms and, by way of example, in Fig. 5, I show one way of accomplishing this purpose. In this view, the throttle valve is provided with a stem 65 having a rack 66 thereon which meshes with a pinion 67 carried by a shaft 68 connected by the bevel gears 69 to the bevel gear 70, the latter gear being arranged to transmit motion to the connected shafts 63 and 46.

If the automatic mechanisms just referred to are both incorporated in a single installation, it will be necessary to render the automatic mechanism associated with the governor valve ineffective when the throt le valve is closed. To this end, I show the bevel gears 62 and 70 arranged to be connected to the shaft 63 by means of an intermediate clutch member 71. When the clutch member 71 connects the gear 62 to the shaft 63, the apparatus is then in position to be operated in response to the governor valve; and, when the clutch member 71 connects the gears 70 to the shaft 63, the apparatus is in position to be operated by the throttle valve. A spring 72 is associated with the clutch member 71 and it serves to connect the bevel gear 62 to the shaft 63.

During closure of the throttle valve, mechanism is brought into play to disengage the clutch 71 against the force of the spring 72 and to engage it with the bevel gear 70, thereby connecting the latter gear to the shaft 63; and further closing movement of the throttle valve will result in the automatic mechanism being operated to shift the turbine rotor to the position of large clearance.

Referring to the clutch shifting mechanism which comes into play at a suitable time during the closing of movement of the throttle valve, I show, by way of example, the stem 65 having an inclined surface 73 (Fig. 6) which is arranged to engage the follower 74 carried by the crank shaft 75, the latter having a crank 76 connected by a suitable linkage at 77, 78 and 79 to the other end of the lever 80 which serves as a shifting lever to shift the clutch 71. As the throttle valve extension 65 moves down, the inclined surface 73 serves to tilt the follower 74 and the linkage is operated to engage the clutch 71 with the gear 70. When the throttle valve is opened, just as soon as the inclined surface 73 passes above the follower 74, the spring 72, preferably connected to the lever 80, then operates to engage the clutch member 71 with the gear 62 to shift the linkage and moves the follower back to a position to be again operated upon by the inclined surface 73.

It is impossible to increase the load on a large turbine without increasing the tension on the synchronizing or speed changing spring. Therefore, within reasonable limits, a given position of load is always identified with approximately a corresponding position of the speed changer adjusting means. In Fig. 7, I show mechanism arranged to be operated by the speed changer mechanism for shifting the rotor either to the small clearance position or to the large clearance position. While mechanism suitable for this purpose may assume various forms, I show, by way of example, a speed changer motor 82 arranged to operate a gear 83 having internal threads engaging with the threaded member 84, the upper end of which is connected to the speed changer spring 85. This mechanism may be utilized to shift the rotor; and, for this purpose, I show the lower end of the member 84 provided with a yoke 86 for engagement with the outer end of the lever 87, the inner end of the lever being connected to a rack 88 meshing with a pinion 89 connected to said operating shaft 46. Suitable movement for the purpose of getting the requisite adjustment may be provided by locating the pivot 90 relatively near to the yoke 86; and, a suitable degree of lost motion may exist between the yoke 86 at the outer end of the lever 87 by the provision of adjusting screws 91.

It will, therefore, be apparent that, when the speed changer is adjusted for a reduction in load, the turbine rotor will be shifted in the large clearance direction. With an increase in load shifting will take place in the other direction.

It is impossible to carry a load on a turbine without first building up steam pressure in the nozzle chamber or inlet passage. Therefore, in Fig. 8, I show apparatus arranged to secure shifting of the turbine rotor in a small clearance direction when steam pressure builds up in the admission chamber or passage to a suitable extent. In this view, I show the steam chamber 93 connected by a pipe 94 with a pressure-responsive device 95, which serves to operate the pilot valve 96 of an operating cylinder 97, the operating piston of the latter being connected to a rack 98 engaging a pinion 99 on said operating shaft 46. Therefore, with an increase in steam pressure in the admission chamber or nozzle passage of the turbine to a suitable extent, the apparatus will be operated to shift the turbine rotor in a small clearance direction. On the other hand, with a drop in pressure, the operating cylinder will move the rotor in a clearance-increasing direction.

Owing to the large proportions of some turbine casings or housings, appreciable distortion takes place on account of atmospheric pressure on the outside of the casing or housing and unequal heating of low pressure portions thereof. It may be impossible, to heat all parts of the structure uniformly and, therefore, rubbing of the elements thereof may occur. Hence, in Fig. 9, I provide pressure-responsive means arranged to move the rotor in a clearance-increasing direction whenever the vacuum drops below a predetermined amount, for example, 23 inches or 24 inches. Should the condenser circulating pump loose its water, the vacuum would drop and the turbine would then operate non-condensing and the apparatus just referred to would be utilized to shift the rotor to a safe position. To this end, I show a pipe 101 connected to the exhaust casing of the turbine and to a pressure-responsive device 102 associated with the relay at 103, the latter operating a rack 104 which meshes with the pinion 105 connected to the operating shaft 46. With this arrangement of apparatus and assuming that the turbine is operating normally, should there be a drop in vacuum, the relay 103 will be actuated to secure shifting of the rotor to increase the clearance. On the other hand, when normal conditions again obtain and a normal vacuum exists in the exhaust casing of the turbine, the relay 103 will shift the turbine rotor in a clearance-decreasing direction.

My invention may also be carried out by electro-mechanical means. For example, in Fig. 10, I show the turbine driving a generator 107, the latter having outlet leads 108. Solenoid means is arranged at 109, such means having means responsive both to current and to voltage. If the load drops below a predetermined amount, the spring 110 will overcome the solenoid 109 and energize the fluid relay 111 to actuate the rack 112 and the pinion 113 carried by said shaft 46 in order to shift the turbine rotor in a clearance-increasing direction. With an increase in load, the energy of the solenoid 109 will overcome the spring 110 and the mechanism will be operated to move the turbine rotor in a clearance-decreasing direction.

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 a casing construction; a rotor; elements carried by the rotor and, in a first axial position of the latter, defining minimum clearances with respect to the casing construction and in a second axial position defining larger clearances of a magnitude avoiding rubbing when the rotor is distorted in starting and stopping the turbine; and means responsive to decrease in turbine load below a predetermined load to shift the rotor to said second axial position so as to define larger clearances of said elements with respect to the casing construction.

2. In a turbine, the combination of a casing construction; a rotor; elements carried by the rotor and, in a first axial position of the latter, defining minimum clearances with respect to the casing construction and in a second axial position defining larger clearances of a magnitude avoiding rubbing when the rotor is distorted in starting and stopping the turbine; means responsive to the admission of steam in excess of a predetermined rate to shift the rotor to the first position and below a predetermined rate to shift the rotor to the second position.

3. In a turbine, the combination of a casing construction; a rotor; elements carried by the rotor and, in a first axial position of the latter, defining minimum clearances and in a second axial position defining larger clearances with respect to the casing construction; a thrust bearing for the rotor and having a housing movable axially with the rotor and relatively to the casing construction; said housing being provided with an external thread; a gear restrained from axial movement by the casing construction

and having internal threads in engagement with the housing threads; a driving gear carried by the housing construction and meshing with the first gear; and means responsive to turbine load conditions for operating the driving gear in order to shift the rotor from one position to the other.

4. In a turbine, the combination of a casing construction; a rotor; elements carried by the rotor and, in a first axial position of the latter, defining minimum clearances and in a second axial position defining larger clearances with respect to the casing construction; abutments associated with the casing construction and with the rotor for limiting the axial movement of the latter; adjustable spacing means connected to one or more of the abutments in order to limit the axial movement of the rotor to one of said positions; and means responsive to load conditions of the turbine for shifting the rotor from one position to the other.

5. In a turbine, the combination of a casing construction; a rotor; elements carried by the rotor and, in a first axial position of the latter, defining minimum clearances and in a second axial position defining larger clearances with respect to the casing construction; abutments provided on the casing construction and spaced axially; a projection arranged between the abutments and connected to move with the rotor; said projection contacting with one abutment when the rotor occupies the first position and with the other abutment when it occupies the second position; and means responsive to turbine load conditions for shifting the rotor.

6. In combination in a turbine, stator structure, a rotor carried by the stator structure and capable of axial movement relatively thereto, a plurality of ring packing elements carried by the stator and by the rotor and defining relatively large clearance when the rotor is in one axial position and relatively small clearance when the rotor is in another axial position, a double-acting thrust bearing carried by the rotor and including a housing, a guide formed in the stator structure and limiting movement of the housing to axial movement, peripheral threads on said housing, a ring having internal threads engaging with said peripheral threads and having peripheral worm teeth, a guide formed in said stator structure for limiting movement of said ring to rotary movement, a shaft carried by the stator structure and having a worm meshing with said worm teeth, and means responsive to an operating condition of the turbine for rotating said shaft either in one direction or the other to cause the rotor to be moved axially.

7. In combination in a turbine, stator structure, a rotor carried by the stator structure and capable of axial movement relatively thereto, a plurality of ring packing elements carried by the stator and by the rotor and defining relatively large clearance when the rotor is in one axial position and relatively small clearance when the rotor is in another axial position, a double-acting thrust bearing carried by the rotor and including a housing, a guide formed in the stator structure and limiting movement of the housing to axial movement, cooperating abutment means carried by said stator structure and by said housing for limiting axial movement of the housing and the rotor, said abutment means being adjustable in order to vary the extent of axial clearance, peripheral threads on the housing, a ring having internal threads engaging the peripheral threads and having peripheral worm teeth, a guide formed in the stator structure and restricting movement of the ring to angular movement, a shaft carried by the stator structure and having a worm meshing with said worm teeth, and means responsive to operating condition of the turbine for turning said shaft either in one direction or the other as operating conditions require.

8. The combination with an elastic fluid turbine having a stator and a rotor, of cooperating packing elements carried by the stator and the rotor, said packing elements being of a type providing close packing clearances in one axial position of the rotor and, in another axial position thereof, providing large safe clearances to avoid rubbing when the rotor is distorted in starting and stopping the turbine, and means responsive to a predetermined minimum load condition of the turbine for moving the rotor to the axial position thereof providing the large safe clearances.

9. The combination with an elastic fluid turbine having a stator and a rotor, of cooperating packing elements carried by the stator and the rotor, said packing elements being of a type providing close packing clearances in one axial position of the rotor and, in another axial position thereof, providing large safe clearances to avoid rubbing when the rotor is distorted in starting and stopping the turbine, and means responsive to a load condition of the turbine and operative when the load is above a predetermined load to move the rotor to the position of close clearances and operative when the load is below a predetermined load to move the rotor to the position of large safe clearances.

10. The combination with an elastic fluid turbine having a stator and a rotor, of cooperating radially-extending packing elements carried by the stator and the rotor, said packing elements, in one axial position of the rotor registering and providing close radial clearances and, in a second axial position of the rotor, being out of registry to

provide clearances between the stator and the rotor which avoid rubbing when the rotor is distorted in starting and stopping the turbine, and means responsive to a load condition of the turbine and operative whenever the load is less than a predetermined load to maintain the rotor in said second axial position.

11. The combination with an elastic fluid turbine having a stator and a rotor, of cooperating radially-extending packing elements carried by the stator and the rotor, said packing elements, in one axial position of the rotor registering and providing close radial clearances and, in a second axial position of the rotor, being out of registry to provide clearances between the stator and the rotor which avoid rubbing when the rotor is distorted in starting and stopping the turbine, and means responsive to a load condition of the turbine and operative to maintain the rotor in said second axial position while the load on the turbine is less than a predetermined load and to maintain the rotor in said first axial position while the load is greater than a predetermined load.

12. The combination with an elastic fluid turbine having a stator and a rotor, of cooperating packing elements carried by the stator and the rotor, said packing elements being of a type providing close packing clearances in one axial position of the rotor and, in another axial position thereof, providing large safe clearances to avoid rubbing when the rotor is distorted in starting and stopping the turbine, and means responsive to a pressure within the turbine which varies with the load carried by the turbine and operative when the pressure corresponds to a load above a predetermined load to move the rotor to the position of close clearances and operative when the pressure corresponds to a load below a predetermined load to move the rotor to the position of large safe clearances.

In testimony whereof, I have hereunto subscribed my name this 16th day of May, 1929.

ROBERT C. ALLEN.