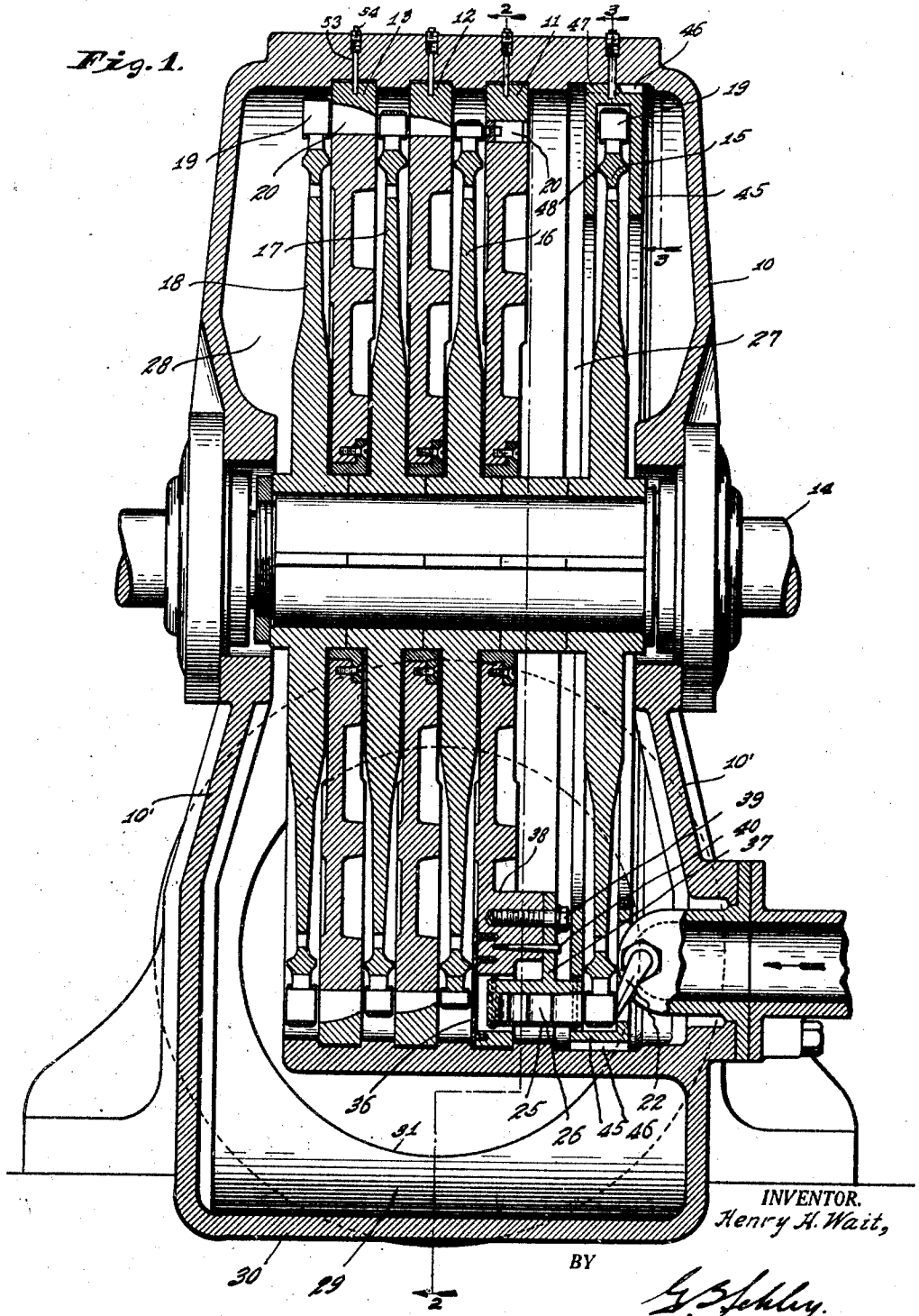
July 30, 1929. H. H. WAIT 1,722,721

COMPOUND TURBINE

Original Filed March 20, 1923 3 Sheets-Sheet 1

Fig. 1.



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COMPOUND TURBINE

Original Filed March 20, 1923 3 Sheets-Sheet 2

Fig. 2.

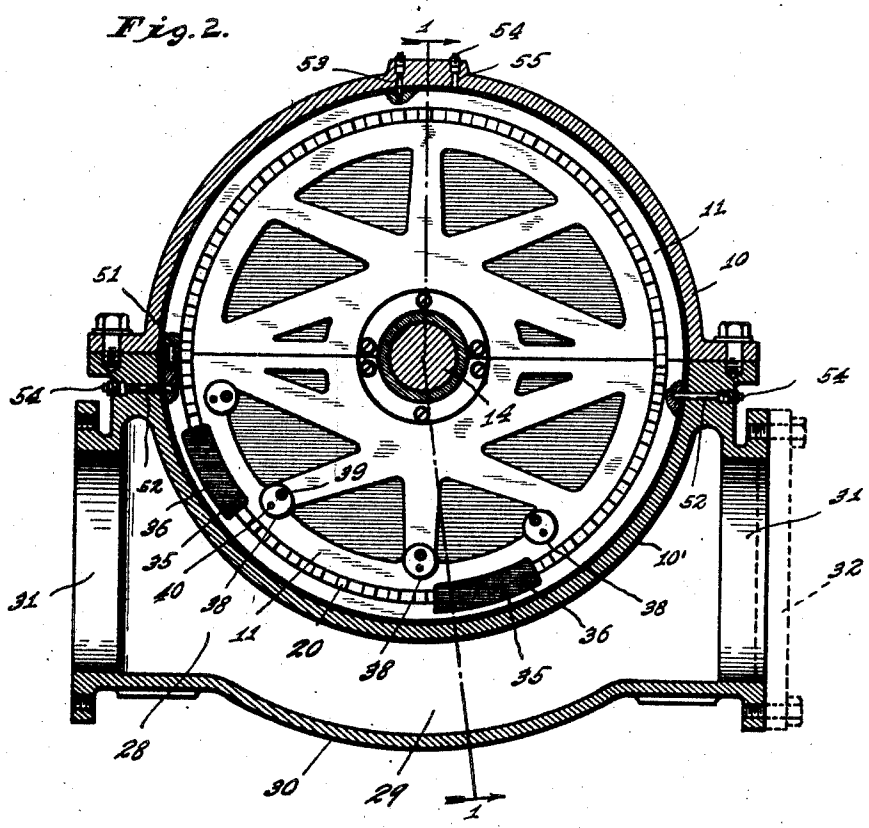
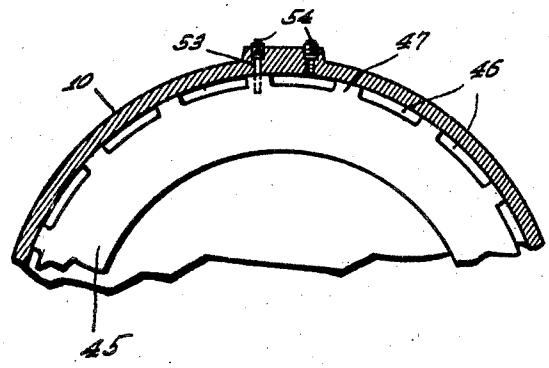


Fig. 3.



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July 30, 1929. H. H. WAIT 1,722,721

COMPOUND TURBINE

Original Filed March 20, 1923 3 Sheets-Sheet 3

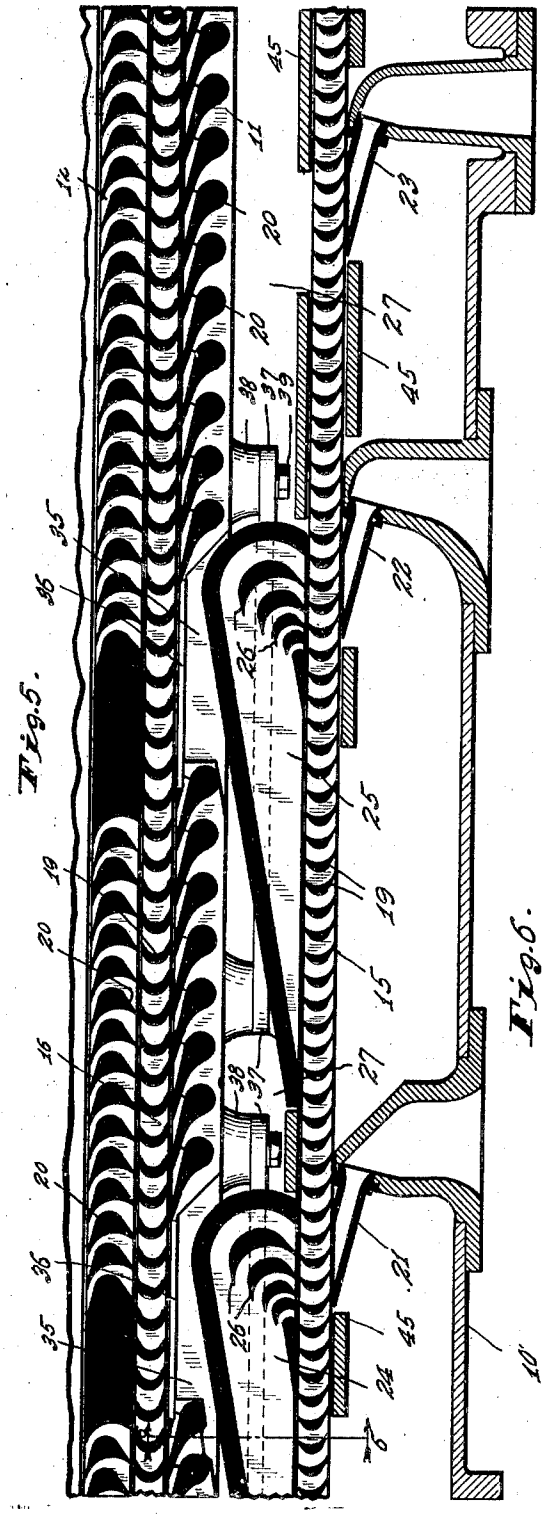

Fig. 5.

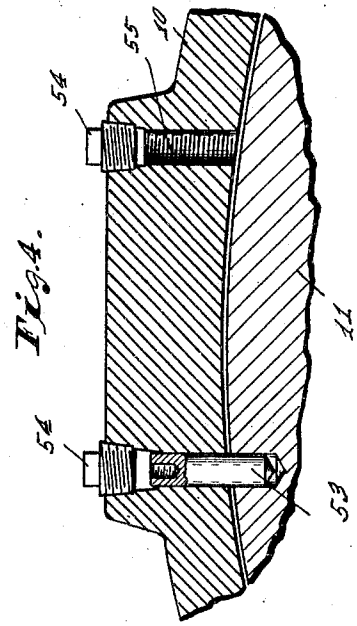

Fig. 4.

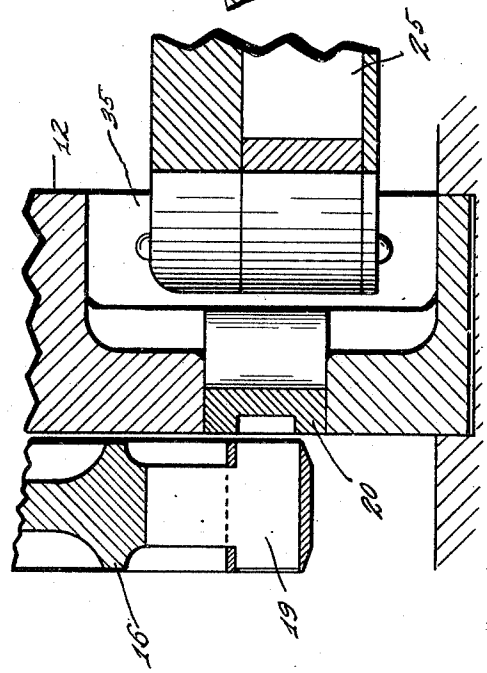

Fig. 6.

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UNITED STATES PATENT OFFICE.

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COMPOUND TURBINE.

Application filed March 20, 1923, Serial No. 626,401. Renewed May 21, 1929.

It is the object of my invention to improve the construction of turbines. More specifically, it is the object of my invention to produce a compound turbine combining the advantages of the re-entrant type and the impulse type, and involving a high-pressure re-entrant turbine wheel and one or more impulse turbine wheels operating at lower pressure, with a plurality of separating diaphragms dividing the turbine into stages; to provide an advantageous and compact arrangement of the return guides of the re-entrant turbine wheel and the adjacent diaphragm, whereby the axial length of the turbine may be shortened, and yet the steam flow through the diaphragm may be interfered with as little as possible by the return guides; to provide a beneficial shroud arrangement for the re-entrant turbine wheel; to provide an effective means for holding the diaphragms and shroud concentric with the shaft and casing, while still permitting the relative expansion due to their different temperature variations; and to provide a steam-exhaust arrangement which will permit the steam to leave the turbine at either side, and to do so efficiently and without undue back pressure.

The accompanying drawings illustrate my invention: Fig. 1 is a vertical longitudinal section through a turbine embodying my invention, taken substantially on the line 1—1 of Fig. 2; Fig. 2 is a transverse section, on a somewhat smaller scale, taken substantially on the line 2—2 of Fig. 1; Fig. 3 is a fragmentary detail section, substantially on the line 3—3 of Fig. 1, to show the mounting of the shroud in the casing to provide the steam passage around the re-entrant turbine wheel; Fig. 4 is a fragmentary enlargement of the upper part of Fig. 2, to show the structure and mounting of one of the guide-pins of a diaphragm on the shroud; Fig. 5 is a fragmentary development of the lower part of the turbine, including the re-entrant turbine wheel and the first impulse turbine wheel, and two of the diaphragms; and Fig. 6 is an enlarged detail section on the line 6—6 of Fig. 5, to show the steam passages behind the return guides to the openings between the blades and the first diaphragm.

The turbine comprises a casing 10 carrying a plurality of diaphragms 11, 12, and 13, which divide the turbine into a plurality of stages, there being three diaphragms for the four-stage turbine shown; and a shaft 14 which carries a plurality of turbine wheels 15, 16, 17, and 18, four in number in such four-stage turbine, one in each stage. The diaphragms 11, 12, and 13 are preferably of the rib-reinforced type which is set forth in my co-pending application Serial No. 620,263, filed February 20, 1923; but it is not essential that they be of that type. The turbine wheels are provided at or near their periphery with suitable blades 19 mounted in a suitable manner; and the diaphragms are similarly provided with suitable blades 20; but the details of such blades 19 and 20 and their mounting form no part of this present invention, and so they are not illustrated in detail.

The first or high-pressure stage of my present turbine, with the turbine wheel 15 therein, is of the re-entrant type; but the remaining turbine wheels 16, 17, and 18 are of the impulse type, and are separated from one another by the diaphragms 12 and 13, and as a group are separated from the high-pressure re-entrant turbine by the diaphragm 11. This combination of a high-pressure re-entrant turbine wheel with one or more lower-pressure impulse turbine wheels is a new construction, so far as I am aware; and I have found that it makes a most efficient combination for abstracting the energy from the steam and converting it into the energy of rotation of the moving element of the turbine.

The re-entrant turbine wheel 15 may be of any suitable construction; and the details of this re-entrant turbine wheel, per se, are not involved in the present invention. This re-entrant turbine wheel 15 is supplied with steam on the high-pressure side by suitable nozzles 21, 22, and 23, the nozzles 21 and 22 being regular-service nozzles, and the nozzle 23 shown being a supplementary or heavy-load nozzle. There may be any number of these nozzles, though the drawings show only three; and all three of these nozzles are shown as located in the lower half of the turbine, at distributed points thereon as indicated by the development shown in Fig. 5.

Opposite the regular-service nozzles 21 and 22, in position to receive steam passing through the turbine wheel 15 from such nozzles, are re-entrant guides 24 and 25. These, per se, may be of any suitable character, with the usual intermediate crescent-shaped guide plates 26; and after receiving steam which has once passed through the turbine wheel

15, they direct such steam back into and through such turbine wheel a second time, in the usual manner of re-entrant-type turbines. The steam after thus passing back through the re-entrant-type turbine wheel 15 finds its way around the outer edge of such wheel into the space 27 between such re-entrant turbine wheel 15 and the diaphragm 11, in which space 27 the steam is relatively quiescent.

No return guide is ordinarily provided opposite the supplementary or heavy-load nozzle 23, as that nozzle is only an emergency nozzle and is not primarily intended for regular use. Therefore, the steam from the nozzle 23 passes only once through the turbine wheel 15, and from such turbine wheel is discharged directly into the space 27. Because the heavy-load nozzle 23 has no return guide opposite it, it may be closer to the nozzle 22 than that nozzle is to the nozzle 21.

From the space 27, the steam passes through suitable nozzle-openings between the blades 20 in the diaphragm 11, into and through the turbine wheel 16; then through suitable nozzle openings between the blades 20 in the diaphragm 12, into and through the turbine wheel 17; then through suitable nozzle openings between the blades 20 in the diaphragm 13, into and through the turbine wheel 18; and thence into the exhaust space 28. In passing through the turbine wheels 16, 17, and 18, the steam acts on the blades 19 thereof in the usual manner of impulse turbines, with small pressure-drop; while in passing through the diaphragms 11, 12, and 13 the steam is expanded and speeded up to the necessary velocity to produce the impulse effect on the respectively succeeding turbine wheels.

The exhaust space 28 is of considerable size between the lowest-pressure turbine wheel 18 and the end wall of the casing 10, and communicates at the bottom with a transverse chamber 29 passing from one side of the turbine to the other. This transverse chamber 29 is formed between the outer face of the lower part 10′ of the turbine-wheel enclosure 10 and the inner face of a lower downwardly bowed wall 30 also formed as part of the housing 10. The chamber 29 is provided with horizontal outlet openings 31 at both ends, or on both sides of the turbine, from either or both of which outlet openings the exhaust steam may be taken off; though usually one of these outlet openings will be closed by a cap plate 32, and the steam will be taken off only from the other. This cap plate 32 is interchangeably mountable over either opening. This arrangement provides a convenient way of getting the exhaust steam from the turbine from either side as desired, with the same turbine structure, and facilitates installation while avoiding the necessity for different structures according to the side from which the exhaust steam is to be taken.

Both return guides 24 and 25 are mounted in the lower half of the casing, in the construction shown; but the return guide 24 extends up beyond the horizontal dividing line between the upper and lower halves of the casing, as indicated by the break in such guide at the left of Fig. 5. This is a desirable construction, thought it is not essential.

In order to shorten the axial length of the turbine, and reduce the distance between bearings, the return guides 24 and 25 extend into openings 35 provided in the diaphragm 11, as is clear from Figs. 1 and 5. These openings 35 preferably extend through the diaphragms, for convenience in construction; but on their low-pressure sides these openings 35 are closed by closing plates 36 suitably attached to the diaphragm 11 and preferably countersunk in the low-pressure face of such diaphragm 11 so that they will be flush with such low-pressure face. The closing plates 36 are relatively thin, to allow as much space as possible for the return guides in the plane of the diaphragm 11, and to provide a steam space behind such return guides.

This steam space is important, and is augmented by the mounting which I provide for the return guides. The return guides are supported wholly from the inside, by inwardly projecting supports, shown as a flange 37 for each return guide. This allows the steam in the space 27 to pass freely around the outside of such return guides. Moreover, this support 37 for the return guides is not only from the inside, but is spaced from the diaphragm 11, by lateral lugs or posts 38, which may be integral with such diaphragm. The flange 37 is fastened to the diaphragm 11 at such lugs or posts by suitable attaching means, such as screws 39 and pins 40. The lugs or posts 38 are spaced inwardly from the inner side of the return guide, to provide open spaces between. By reason of these lugs or posts 38, and of the wholly internal support for the return guides, the steam in the space 27 can circulate all around such return guides, and into the spaces 35; so that the gaps in the series of blades 20 of the diaphragm 11 and in the nozzle spaces between such blades may be as short circumferentially as possible, and so that in spite of the axial shortening of the turbine by the projection of the return guides into the plane of the diaphragm 11 it may be possible to use almost the entire circumference of such diaphragm for the blades 20 and the nozzle spaces which they provide.

Around the outer part of the re-entrant-type turbine wheel 15, I provide a shroud 45. This is in general U-shaped in cross-

section, with the base of the U closely circumferentially surrounding the periphery of the turbine wheel 15, and with the legs of the U projecting inward as flanges from such base on the sides of such turbine wheel past the blades 19 thereof. The inwardly projecting flange on the high-pressure side is cut away to provide openings for the nozzles 21, 22, and 23; and also to provide openings opposite the discharge parts of the return guides 24 and 25, so that there will be no backing up of the steam flow through the turbine wheel 15. On the low-pressure side of the turbine wheel 15, the flange of the shroud is cut away to provide spaces for the return guides 24 and 25. A development of this shroud for the lower part of the turbine is shown in Fig. 5; but the flanges are continuous throughout the whole of the upper half of the shroud, save where the toe of the return guide 24 projects upward into such upper half, which is beyond the left end of the development view of Fig. 5.

In order that the steam which has passed twice through the re-entrant turbine wheel 15 may again pass by the plane of such turbine wheel and into the space 27, I provide steam passages 46 across such plane outside of the shroud 45. These steam passages 46 are formed by making the shroud with an outer series of supporting feet 47 which bear against the inside of the casing 10, the passages 46 being between the feet 47, as is clear from Fig. 3. The outer edge of the shroud 45 is set in an internal circumferential groove in the casing 10, and the diaphragms 11, 12 and 13 are set in similar internal circumferential grooves in such casing 10; but the groove which receives the shroud 46 differs from the other grooves in that it is wider than the part it receives. This is so that the side walls of said groove will not stop the passages 46.

By having the shroud 45, I am able to reduce the rotation loss incident to the re-entrant turbine wheel 15. This reduction in rotation loss is augmented by an annular rib 48 on each face of the turbine wheel 15 just inside of the blades 19 of such wheel. These ribs 48 project axially into close proximity to the flanges of the shroud 45. The shroud and these ribs serve to break up the currents in the surrounding medium caused by the rotation of the turbine wheel 15; as in any such rotating wheel the steam in engagement with the surface of the rotating member is entrained and thrown outward, and this involves an inflow along the surface of the shroud 45. By this shroud and these ribs, the free flow of this entrained steam is largely prevented, and the loss caused thereby is minimized.

Each of the diaphragms 11, 12, and 13 and the shroud 45 is supported concentrically with the casing 10, by a special supporting arrangement which permits the relative expansion and contraction of the casing 10 and such diaphragm or shroud. This supporting arrangement is the same for each diaphragm and for the shroud, and therefore it is shown specifically only in connection with one of the diaphragms, illustrated in Fig. 2. Each diaphragm and the shroud is made in two parts, an upper part and a lower part, with the parting line substantially on the horizontal diameter. The outer edge of each diaphragm and the shroud is received in an integral groove in the casing 10, as already stated; and the diaphragm fits closely within these grooves, because they must support an axial pressure which is at times very heavy, sometimes amounting to several tons; but the shroud is not subjected to any such axial pressure, and for that reason also need not fit closely in its groove in the inner face of the casing. By this axial pressure, each diaphragm is firmly seated against one side wall of its groove. The two halves of each diaphragm or the shroud are held in proper relative position, with respect to each other, by one or more dowel pins 51. I prefer to use only a single dowel pin, as is illustrated in Fig. 2, though it is not essential that there be no more than one. If only one dowel pin is used, it may be any place along the parting line, although I have shown it near one end thereof. This dowel pin makes the two halves of the diaphragm, or of the shroud, expand and contract together horizontally. The lower half of each diaphragm, or of the shroud, has near the horizontal parting line between it and the upper half two supporting and guiding pins 52, which project horizontally inward from the casing 10 into a horizontal hole parallel to such parting line, and fairly close thereto. The pin 52 preferably has a tight fit in such hole, but the fit is not sufficiently tight to prevent movement of the diaphragm or shroud on such pin longitudinally thereof. Preferably the two pins 52 are in alinement, though that is not essential. The diaphragm, or the shroud, may contract or expand horizontally, or along a horizontal diameter, with respect to the casing, but this horizontal diameter of the diaphragm or the shroud is held substantially co-incident with the horizontal diameter of the casing by the pins 52. Thus the pins 52 hold the diaphragm, or the shroud, concentric with the casing so far as vertical movement is concerned. To hold the diaphragm, or the shroud, concentric with the casing so far as horizontal movement is concerned, I preferably provide a guide pin from the casing into the diaphragm or shroud close to the vertical diameter. I have shown such a vertical guide pin 53 projecting from the casing 10 into the upper half of the diaphragm, in Fig. 2, and doing

so close to the vertical diameter. By this guiding pin 53, which is similar to the guiding pin 52, the diaphragm, or the shroud, is prevented from becoming centrally displaced horizontally with respect to the casing, so far as the center of the casing and diaphragm are concerned. In other words, the pin 53 holds the diaphragm, or the shroud, concentric with the casing, so far as relative horizontal movements are concerned. Thus the pins 52 and the pin 53 together serve to hold the diaphragm, or the shroud, concentric both vertically and horizontally with respect to the casing.

One of the pins 52 or 53 is shown in detail in Fig. 4. It comprises merely a pin driven tightly through a hole in the casing 10, and into an alined hole in the diaphragm or shroud. The outer edge of the hole in the casing is counter-sunk, and may be closed by a screw-plug 54, which is separate from the pin 52 or 53, and is merely a hole-closing device. To remove a pin 52 or 53, the screw-plug 54 is first removed; which renders accessible the outer end of the pin. Then a threaded instrument is inserted into a threaded hole provided in the outer end of the pin 52 or 53, and such pin is withdrawn. If desired, an additional hole 55 may be provided in the casing 10, and may also be closed by a screw-plug 54; and when this hole 55 is open it is possible to insert a push-rod to force the diaphragm-half or shroud-half out of the casing-half in which it is mounted. The hole 55 is also preferably located close to the vertical diameter, as is clear from Fig. 2. Such a push-hole 55 is especially desirable in the upper casing-half, where I have illustrated it.

I claim as my invention:—

1. In a steam turbine, the combination of a casing, one or more turbine wheels therein, a normally stationary annular part projecting inward from the casing but separable therefrom and movable relatively thereto upon relative changes in temperature and bearing axially thereagainst on flat surfaces on which the two parts are relatively slidable upon such relative changes in temperature, and supporting and guiding means projecting from said casing into said annular part wholly on two lines substantially perpendicular to each other.

2. In a steam turbine, the combination of a casing, one or more turbine wheels therein, a normally stationary annular part projecting inward from the casing but separable therefrom and movable relatively thereto upon relative changes in temperature and bearing axially thereagainst on flat surfaces on which the two parts are relatively slidable upon such relative changes in temperature, and supporting and guiding means projecting from said casing into said annular part wholly on two lines substantially perpendicular to each other and close to the diameters which they parallel but spaced from such diameter in the case of at least one such line.

3. In a steam turbine, the combination of a casing, one or more turbine wheels therein, a normally stationary annular part projecting inward from the casing but separable therefrom and movable relatively thereto upon relative changes in temperature and bearing axially thereagainst on flat surfaces on which the two parts are relatively slidable upon such relative changes in temperature, said annular part being divided substantially along a diameter, supporting and guiding means projecting from said casing into said annular part substantially parallel to and close to said division line, and another guiding means projecting from said casing into said annular part substantially perpendicularly to said division line and near the diameter which is perpendicular to the division line, said casing and said stationary annular part being free from interconnecting guiding means between them save on the lines specified.

4. In a steam turbine, the combination of a casing, one or more turbine wheels therein, a normally stationary annular part projecting inward from the casing but separable therefrom and movable relatively thereto upon relative changes in temperature and bearing axially thereagainst on flat surfaces on which the two parts are relatively slidable upon such relative changes in temperature, said annular part being divided substantially along a diameter, supporting and guiding means projecting from said casing into said annular part substantially parallel to said division line, and another guiding means projecting from said casing into said annular part substantially perpendicularly to said division line, said casing and said stationary annular part being free from interconnecting guiding means between them save on the lines specified.

5. In a steam turbine, the combination of a casing, one or more turbine wheels therein, a normally stationary annular part projecting inward from the casing but separable therefrom and movable relatively thereto upon relative changes in temperature and bearing axially thereagainst on flat surfaces on which the two parts are relatively slidable upon such relative changes in temperature, said annular part being divided substantially along a diameter, supporting and guiding means projecting from said casing into said annular part substantially parallel to said division line, and another guiding means projecting from said casing into said annular part substantially perpendicularly to said division line, said casing and said stationary annular part being free from interconnecting guiding means between them save on the lines specified, and means for

interlocking the portions of said annular part so that such portions move together in their expansion and contraction.

6. In a steam turbine, the combination of a casing, one or more turbine wheels therein, a normally stationary annular part projecting inward from the casing but separable therefrom and movable relatively thereto upon relative changes in temperature and bearing axially thereagainst on flat surfaces on which the two parts are relatively slidable upon such relative changes in temperature, supporting and guiding means projecting from said casing into said annular part horizontally near the horizontal diameter, and a guide pin projecting from said casing into said annular part vertically near the vertical diameter, said turbine being free from any guiding means between said casing and said annular part save at the places specified.

7. In a steam turbine, the combination of a casing, one or more turbine wheels therein, a normally stationary annular part projecting inward from the casing but separable therefrom and movable relatively thereto upon relative changes in temperature and bearing axially thereagainst on flat surfaces on which the two parts are relatively slidable upon such relative changes in temperature, supporting and guiding means projecting from said casing into said annular part horizontally, and a guide pin projecting from said casing into said annular part vertically, said turbine being free from any guiding means between said casing and said annular part save at the places specified.

8. In a steam turbine, the combination of a casing, one or more turbine wheels therein, a normally stationary annular part projecting inward from the casing but separable therefrom and movable relatively thereto upon relative changes in temperature and bearing axially thereagainst on flat surfaces on which the two parts are relatively slidable upon such relative changes in temperature, said annular part being divided substantially along a horizontal diameter, supporting and guiding means projecting horizontally from said casing into the lower portion of said annular part near the horizontal diameter, and a guide pin projecting vertically from said casing into the upper portion of said annular part vertically near the vertical diameter.

9. In a steam turbine, the combination of a casing, one or more turbine wheels therein, a normally stationary annular part projecting inward from the casing but separable therefrom and movable relatively thereto upon relative changes in temperature and bearing axially thereagainst on flat surfaces on which the two parts are relatively slidable upon such relative changes in temperature, said annular part being divided substantially along the horizontal diameter, supporting and guiding means projecting from said casing into the lower portion of said annular part horizontally, and a guide pin projecting from said casing into the upper portion of said annular part vertically.

10. In a steam turbine, the combination of a casing, one or more turbine wheels therein, a normally stationary annular part projecting inward from the casing but separable therefrom and movable relatively thereto upon relative changes in temperature and bearing axially thereagainst on flat surfaces on which the two parts are relatively slidable upon such relative changes in temperature, and supporting and guiding means projecting from said casing into said annular part, said supporting and guiding means being located wholly on two lines substantially perpendicular to each other.

11. In a steam turbine, the combination of a casing, one or more turbine wheels therein, a normally stationary annular part projecting inward from the casing but separable therefrom and movable relatively thereto upon relative changes in temperature and bearing axially thereagainst on flat surfaces on which the two parts are relatively slidable upon such relative changes in temperature, and supporting and guiding means projecting from said casing into said annular part, said supporting and guiding means being located wholly on horizontal and vertical lines.

In witness whereof, I have hereunto set my hand at Indianapolis, Indiana, this 19th day of March, A. D. one thousand nine hundred and twenty-three.

HENRY H. WAIT.