Feb. 7, 1933. O. D. H. BENTLEY 1,896,809

MULTISTAGE TURBINE

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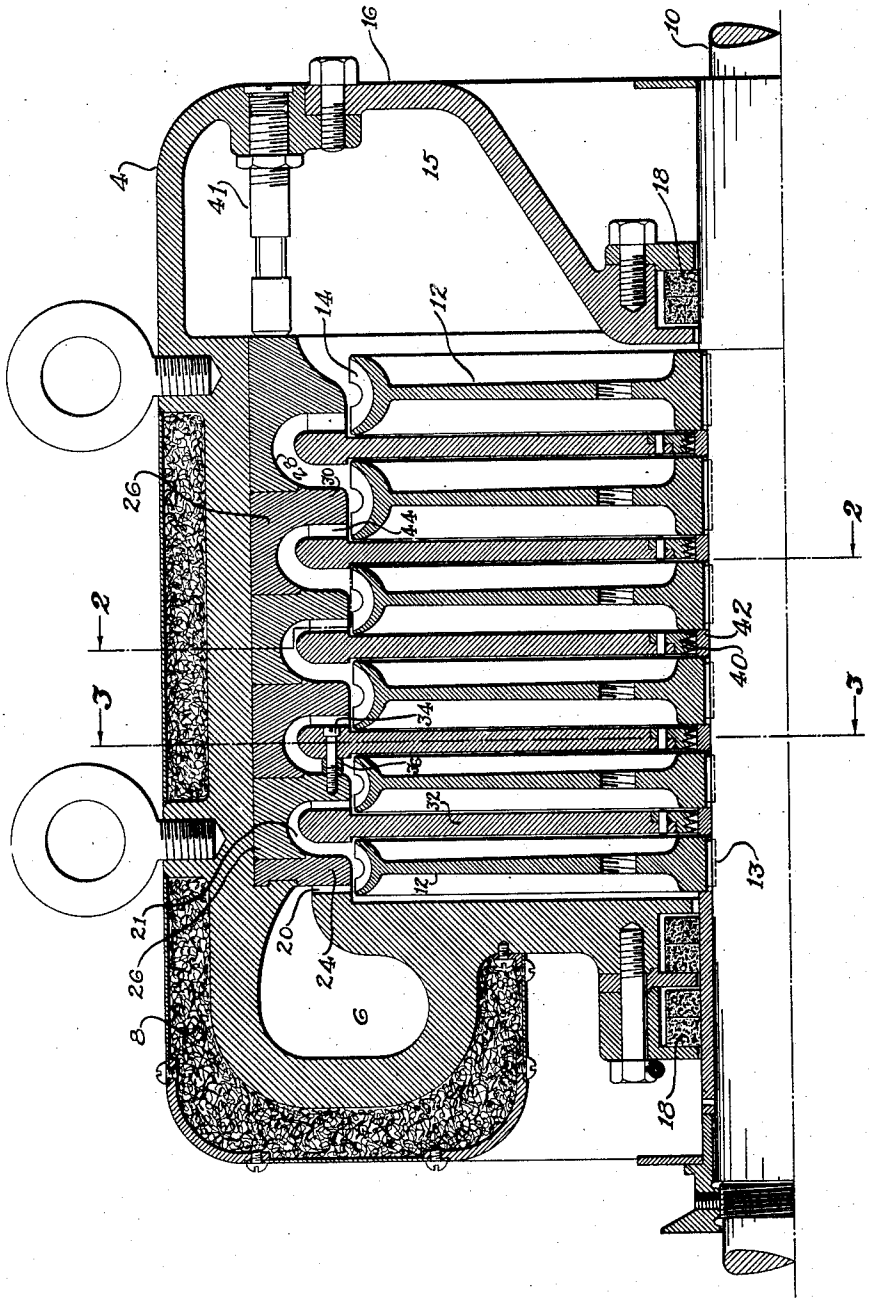



Fig. 1

Witness

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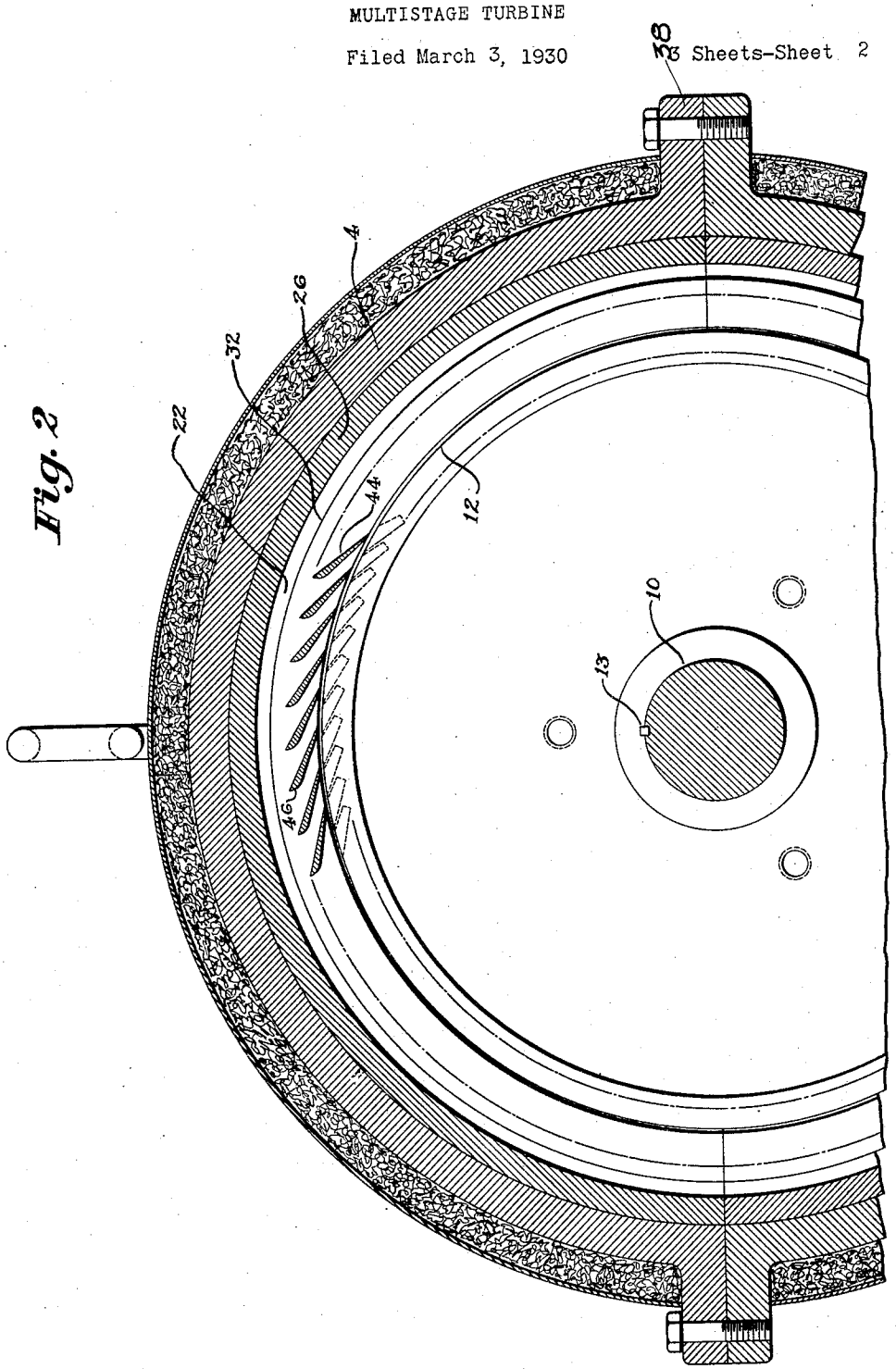
Van Eaton, Finch, Hildreth & Cary

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Fig. 2




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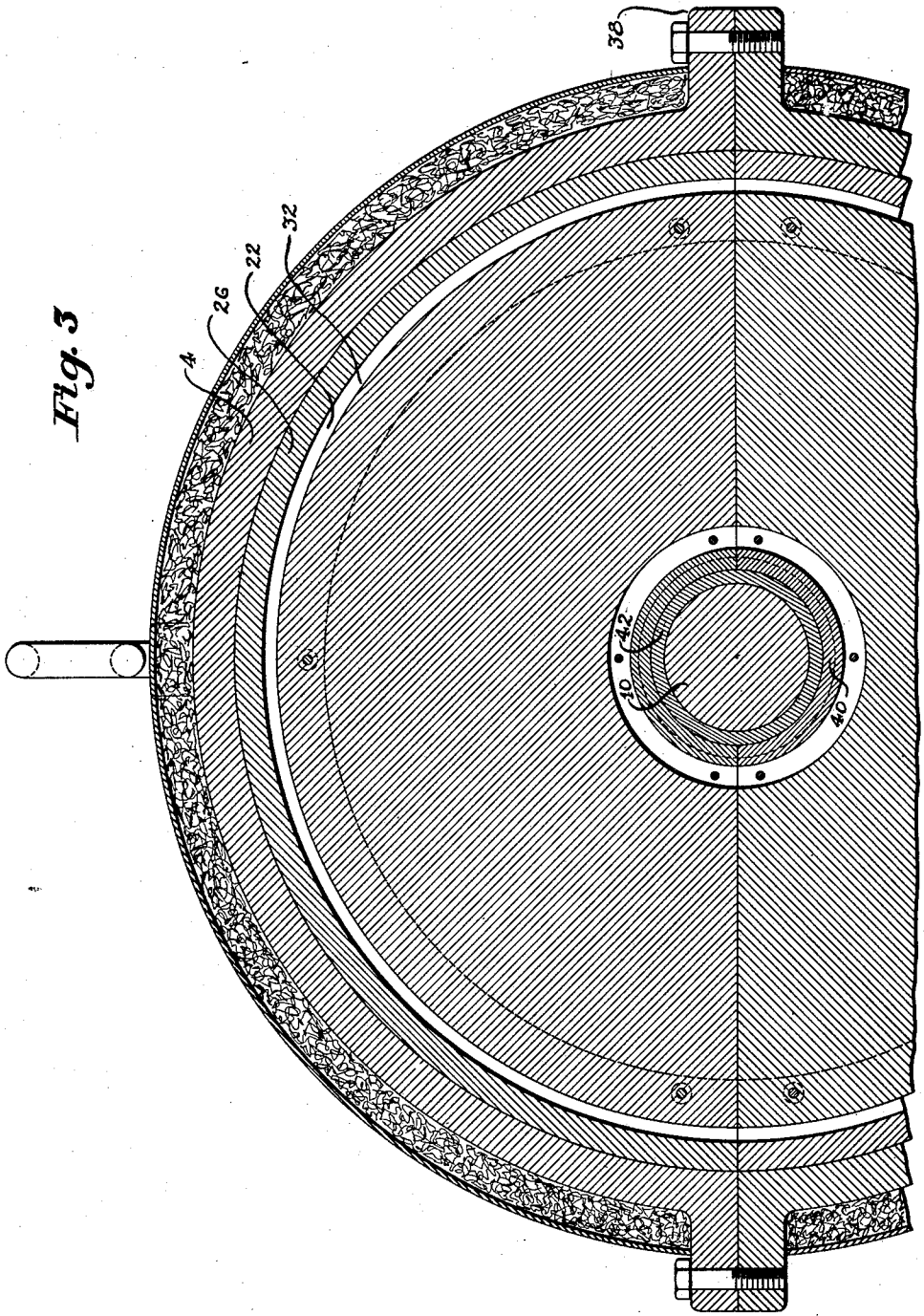
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Fig. 3




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Patented Feb. 7, 1933

1,896,809

# UNITED STATES PATENT OFFICE

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## MULTISTAGE TURBINE

Application filed March 3, 1930. Serial No. 432,637.

The present invention relates to multi-stage turbines.

The principal object of the present invention is to provide a multi-stage turbine of high efficiency and of readily manufactured construction.

With this and other objects in view, as will hereinafter appear, the present invention contemplates the provision of a turbine having a plurality of rotors or wheels with means for admitting the steam or other elastic working fluid to the several rotors in succession according to the radial flow principle. The radial flow construction is common for single stage turbines, but for multi-stage turbines, the so-called axial flow principle is ordinarily employed. The radial flow construction, according to the present invention, is to be preferred not only because of such manufacturing advantages as simplicity, compactness, and ease of assembly, but also because of the greater utilization of the energy of the fluid.

In the accompanying drawings, Fig. 1 is a longitudinal sectional elevation of the preferred form of turbine; Fig. 2 is a section on line 2—2 of Fig. 1; and Fig. 3 is a section on line 3—3 of Fig. 1.

The illustrated embodiment of the invention comprises a turbine having a casing 4 provided with an inlet steam chest 6. The casing is suitably lagged with heat insulating material 8. The shaft 10 is of usual form and is secured to a series of rotors 12 by keys 13. Each rotor has peripheral or radial flow buckets 14. The buckets of the several rotors are of increasing size from the inlet to the exhaust end of the turbine to accommodate the increasing volume of steam. The last stage exhausts into an outlet chamber 15 which is closed by a conical end piece 16 bolted to the casing. The usual glands or stuffing boxes 18 are provided to prevent leakage along the shaft.

From the steam chest 6 the steam is admitted to the first rotor through an annular passage 20. The steam from this rotor is exhausted radially into an annular inter-stage fluid directing passage 21 from which it is admitted according to the radial flow principle to the next succeeding rotor. Other similar annular inter-stage fluid directing passages 21 receive the exhaust steam from one rotor and deliver it to the next in succession, until it is finally discharged from the last rotor into the exhaust or outlet chamber 15.

One of these passages 21, namely, the passage between the third and fourth rotors, is indicated at 22 in Fig. 2. All of the inter-stage passages are of similar form but are of increasing size toward the exhaust end of the turbine in order to accommodate the increased volume of steam as the pressure decreases. The annular inter-stage passages are formed in the stator of the turbine in the following manner: Adjacent to the steam chest 6 a ring 24 is fitted into the casing surrounding and close to the first rotor. A series of closely fitted adjoining rings 26 is received in the casing. Each ring has an internal annular machined groove 28 of general toroidal contour forming the outer boundary of each inter-stage passage. Each ring has an inwardly extending flange portion 30. Extending into each annular chamber formed by the rings 26 is a diaphragm or separating plate 32 having an outer toroidal surface defining the inner bounding surface of each inter-stage passage. Each diaphragm is secured to and spaced from the next preceding ring 26 by means of a plurality of bolts 34 and spacing washers 36, only one of which is shown in Fig. 1.

As shown in Figs. 2 and 3, each ring 26 and each diaphragm 32, as well as the ring 24 and the casing, are constructed in two parts secured by bolting flanges 38 to facilitate assembly. The turbine may be disassembled by removing the end cap 16 and separating the casing, after which the entire upper half of the stator, including the half-rings and half-diaphragms may be lifted off. The rings are tightly secured against endwise play by a plurality of pressure bolt assemblies, one of which is shown at 41, secured in the outer end of the casing and bearing against the outermost ring.

At the center of each diaphragm is secured a serrated plate 40 which engages and wears into a soft metal bearing 42 on the shaft to prevent leakage of fluid along the shaft.

The several steam admission passages including the initial passage 20 and the entrance sides of the inter-stage passages 21, are provided with vanes to direct the steam into the buckets along nearly tangential lines. For the inter-stage passages, these vanes, which are indicated at 44, are milled or cut out of the outer faces of the diaphragms 32. Each vane is therefore integral with the diaphragm and projects outwardly therefrom to engage closely with the next adjacent of the rings 26. As shown in Fig. 2, adjacent vanes have parallel fluid directing surfaces, and thus the vanes are necessarily of tapered form, being of less thickness at their inner than at their outer ends. The straight parallel sides of the vanes are of considerable length, at least as great as the perpendicular distance between adjacent vanes, to form a fluid directing throat. Each vane is rounded at its outer end 46 to permit non-turbulent entrance of fluid into the throat.

The ring 24 on the inlet side (that is, the left side, as viewed in Fig. 1), is similarly formed with vanes extending into the passage 20.

The vanes 44, acting to direct the fluid to the rotor in a nearly tangential direction, form nozzles which nozzles, however, are not necessarily of the expanding type. Straight sided nozzles, as shown in the drawings, may be used when the steam in any nozzle does not expand to such extent that the pressure is less than 58% of the pressure at the inlet of the nozzle. In a six-stage turbine, the pressure drop in any stage will not ordinarily be great enough to require expanding nozzles. Thus, in the illustrated embodiment of the invention, if the steam expands to 58% pressure in each stage, the exhaust steam pressure is less than 4% of the initial pressure. Ordinarily, this represents a greater expansion than can be taken care of in a single turbine, but if further expansion is necessary, it may be effected by the use of additional stages, or by cutting the vanes 44 in expanding form.

It will be seen that the invention provides for radial flow in each stage of a multi-stage turbine. It will be understood that the term "radial flow" as employed herein, is as usually employed in this art, to signify a radial component of flow and to distinguish from "axial flow" by the total absence of any axial or longitudinal component. The radial flow principle permits the extraction of a greater proportion of useful energy from the steam in any single stage because of the fact that the fluid, in entering and leaving the buckets, turns completely through an angle of 180°.

Having thus described the invention, what is claimed is:

1. A multi-stage, elastic fluid turbine comprising a shaft, a plurality of rotors each provided with a series of peripherally disposed buckets, and means forming radial flow inter-stage passages between adjacent rotors, said means comprising a diaphragm having a periphery rounded in axial cross-section and separating the rotors and a ring surrounding the diaphragm and having an annular internal groove of corresponding rounded axial cross-section and spaced from the outer surface of the diaphragm, and fluid directing vanes in the inter-stage passages.

2. A multi-stage, elastic fluid turbine comprising a shaft, a plurality of rotors each provided with a series of peripherally disposed buckets, and means forming radial flow inter-stage passages between adjacent rotors, said means comprising a diaphragm separating the rotors and a ring surrounding the diaphragm and having an annular internal groove spaced from the outer surface of the diaphragm, and fluid directing vanes formed on the diaphragm and projecting into the inter-stage passages.

3. A multi-stage, elastic fluid turbine comprising a shaft, a plurality of rotors each provided with a series of peripherally disposed buckets, and means forming radial flow inter-stage passages between adjacent rotors, said means comprising a diaphragm separating the rotors and a ring surrounding the diaphragm and having an annular internal groove spaced from the outer surface of the diaphragm, each diaphragm and ring being split, and bearing means between the diaphragm and the shaft.

4. A multi-stage, elastic fluid turbine comprising a shaft, a plurality of rotors along the shaft, each rotor having symmetrical peripherally disposed action buckets U-shaped in axial section, a stator having annular interstage chambers between adjacent rotors, each chamber being U-shaped in axial section, and means separating the rotors having U-shaped portions extending beyond the rotors and within the chambers to form continuous U-shaped interstage passages.

In testimony whereof I have signed my name to this specification.

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