

Nov. 22, 1966

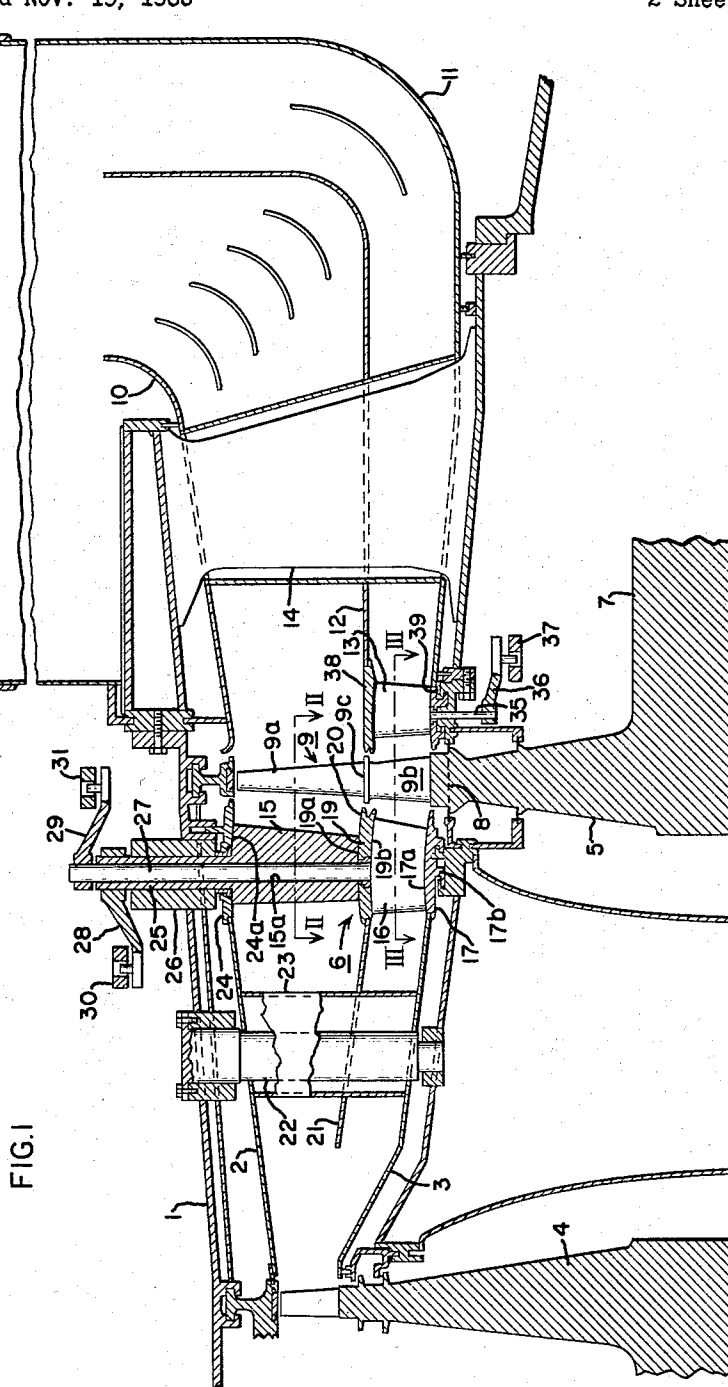
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3,286,983

REVERSIBLE AXIAL FLOW GAS TURBINE

Filed Nov. 19, 1965

2 Sheets-Sheet 1



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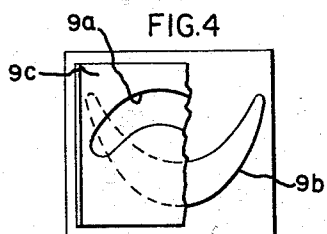
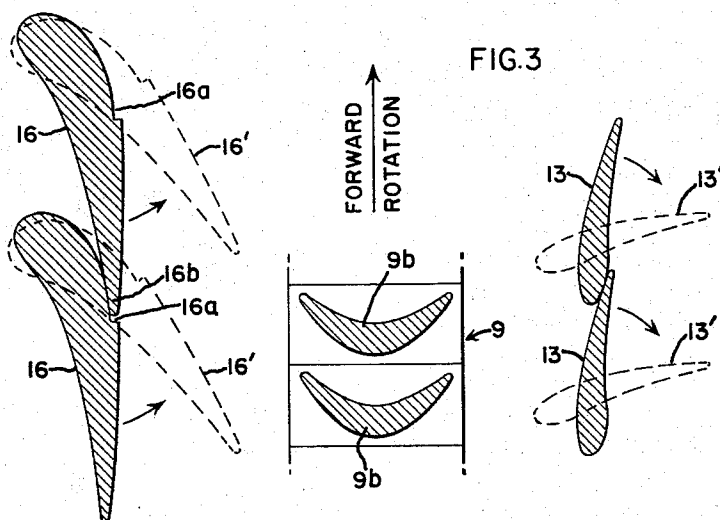
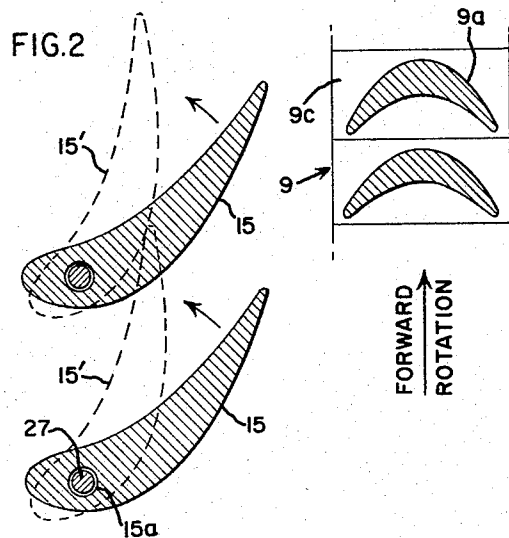
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REVERSIBLE AXIAL FLOW GAS TURBINE
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Filed Nov. 19, 1965, Ser. No. 508,724
4 Claims. (Cl. 253—73)

This invention relates to an axial flow gas turbine, wherein the load turbine is reversible. More particularly, the invention relates to improved variable vane structure and turbine blade structures suitable for operating the load shaft of a two-shaft gas turbine in either direction and at varying speed or load.

It is desirable in some instances to provide an elastic fluid turbine with additional means to reverse the direction of rotation of the output shaft, such as in marine propulsion units where astern operation is necessary. Although gas turbines have been used in a few marine propulsion systems, one of the major problems has been that of providing suitable and economical astern operation. There have been several suggestions for reversing the propeller shaft without reversing the gas turbine shaft. U.S. Patent 2,912,824 issued to F. H. Van Nest et al. on November 17, 1959, discloses a marine gas turbine powerplant, wherein astern power is provided by a reversible pitch propeller. Other means for obtaining reverse power have included suggestions for fluid or friction clutches with reverse gear or suggestions for intermediate electric drives.

It has been suggested in marine propulsion systems for steam turbines that two concentric rows of blades on a single wheel, one of the rows having reversed curvature, can be employed to obtain forward or reverse rotation of the turbine wheel. However, selective admission of motive fluid to the desired row is easily accomplished under steam turbine practice by means of opening external valves to admit steam through fixed nozzle partitions in a "nozzle box." This type of control of the motive fluid is unsuitable for a gas turbine since the combustion products cannot simply be "bottled up" in the manner that steam can. Accordingly, the adjustment of motive fluid power and flow through turbine buckets in conventional axial flow gas turbines is either accomplished by controlling addition of fuel (in a single shaft gas turbine), or by adjusting the ratio of pressure drops across two independent turbine stages (in a two-shaft gas turbine) as disclosed in the aforementioned Van Nest patent. A suitable variable area adjustable nozzle to accomplish division of power between stages in a two-shaft gas turbine is disclosed in U.S. Patent 2,919,890 issued to A. N. Smith et al. on January 5, 1960.

One of the problems encountered when turbine buckets are provided with two concentric rings of blades with opposite curvatures is that of the large rotation losses which prevail in the set of blades which are rotating backwards. These rotation losses can amount to a substantial portion of the total power produced by the blades rotating in the forward direction. Although operating considerations will often tolerate relatively large losses when the turbine is operated in reverse (since this takes place a relatively small percentage of the time), these rotation losses must be held to an absolute minimum when the turbine is operating in the forward or most efficient mode.

Prior constructions have suggested closing off entry of motive fluid at the inlet to the reversing bucket row. One such arrangement is disclosed in my copending application Serial No. 430,085 filed February 12, 1965, and assigned to the present assignee. However, calculations show that losses in some cases might amount to 10 to

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15% of the total power, which makes these arrangements less desirable.

Accordingly, one object of the present invention is to provide an improved reversible axial flow gas turbine with a minimum of rotation losses from backwardly turning blades.

Another object of the invention is to provide an improved gas turbine adjustable vane structure for accomplishing shaft reversal and minimizing rotation losses in a reversing axial flow gas turbine.

Briefly stated, the invention is practiced by providing a gas turbine wheel with a reversing blade row. Two sets of adjustable vanes are provided, one at the inlet and one at the outlet of the blade row. Means are provided for pivoting the adjustable vanes to closed position on either side of the reversing blade row to effect a smooth enclosure for reducing losses due to backward rotation of the blades. When the adjustable vanes are opened, they control entry and guiding of motive fluid used for reversing the wheel.

Other objects and advantages of the invention will become apparent from the following description taken in connection with the accompanying drawing in which:

FIG. 1 is a simplified schematic elevation view, taken in section, of a portion of the gas turbine nozzle and bucket assembly,

FIG. 2 is a cross section taken through the outer turbine elements along lines II—II of FIG. 1,

FIG. 3 is a section taken through the "reverse" turbine elements along lines III—III of FIG. 1, and

FIG. 4 is a top view, partly in section, of one turbine bucket.

Referring now to FIG. 1 of the drawing, a portion of the turbine casing 1 supports annular flow guiding duct walls 2, 3. Walls 2, 3 conduct hot motive fluid from a "compressor turbine" wheel 4 on one shaft to a load turbine wheel 5 on another separate shaft by way of an adjustable nozzle assembly shown generally as 6.

Although not material to the present invention, turbine wheel 4 drives a suitable multi-stage axial flow compressor furnishing air to a combustion chamber where fuel is burned. Turbine wheel 4 provides no useful power but when acting in conjunction with its compressor and combustion chamber, serves as a hot gas generator or source of motive fluid. Other suitable sources of hot motive combustion fluid can be provided by the use of converted aircraft jet engines suitably arranged to discharge into duct walls 2, 3.

The turbine wheel 5 provides useful power through an output load shaft 7 which may be directly coupled to a ship's propeller with gears. Disposed about the periphery of wheel 5 in suitable dovetail slots, indicated at 8, are a number of radially directed bucket members 9. The radially outer portion of bucket member 9 comprises a blade portion 9a shaped to provide forward rotation of the turbine wheel 5 in the usual manner. The radially inner portion is a blade portion 9b with reverse curvature to provide astern operation or reverse rotation of wheel 5. Blade portions 9a, 9b are separated by an intermediate platform portion 9c which extends circumferentially to abut similar platforms on other bucket members 9 and to thereby provide a circumferential flow separating wall. Reference to FIG. 4 of the drawing illustrates a top view of bucket members 9 showing the opposite curvatures of blade portions 9a, 9b.

On the downstream end of turbine wheel 5, a curved outer annular wall 10 and an inner annular wall 11 provide a common exhaust duct for gas from either the inner or outer ring of bucket members 9. A suitable dividing

wall 12 with adjustable exit vanes 13 and supporting struts 14 is provided.

Referring more particularly now to the variable nozzle assembly 6, this consists of an outer circumferential row of radially directed and movable nozzle partitions or vanes 15 arranged to direct motive fluid into the outer ring of turbine blade portions 9a. Radially inward from and concentric with partitions 15 is an inner circumferential row of radially directed and movable nozzle partitions or vanes 16.

The radially innermost boundary for the motive fluid is provided by means of an annular member 17 having an outer surface 17a which is a portion of a sphere and having an inner flange 17b arranged to slide within a groove in a suitable stationary wall 18 for thermal expansion and contraction.

Radially separating the nozzle partitions 15 and 16 is an intermediate annular member 19 with spherical surfaces on its upper and lower sides at 19a and 19b, respectively. Member 19 has a suitable sealing lip 20 co-operating with the platforms 9c of the bucket wheel. It is provided with a suitable extension 21 extending upstream into the annular duct defined between walls 2, 3 to divide the flow. Member 19 and extension 21 are supported by means of struts 22 extending through the walls of casing 1. Struts 22 are provided with streamlining heat shields 23.

The outer boundary surface for motive fluid is provided by means of an outer annular member 24 with an inner spherical surface 24a. The center of curvature for all of the spherical surfaces 17a, 19a, 19b, and 24a is located on the turbine shaft axis so that the partitions may pivot about a radial axis without binding the stationary structure or each other. The annular members 17, 19, or 24 may be full rings or may be suitably constructed in segmented fashion by means well known in the art to provide for thermal expansion and contraction.

Attached to the radially outer part of each of the outer partitions 15 is a radially extending operating stem 25. Stem 25 is hollow and is mounted for rotation within a bushing 26. In a similar manner, attached to the radially outer end of each of the inner partitions 16 is a radially extending operating stem 27. This extends outward through a radial hole 15a inside each of the outer partitions 15 and through the hollow stem 25. Operating levers 28, 29 are attached to stems 25, 27, respectively.

In this manner, outer nozzle partitions 15 can be pivoted about a radial axis with levers 28 to vary the effective flow area of the outer gas path independently of nozzle partitions 16 which can be pivoted by levers 29 to vary the effective flow area of the inner gas path. Inner and outer nozzle actuating ring members 30 and 31 are attached by pins to each of the inner and outer sets of circumferentially spaced operating levers 28, 29 so that the entire ring of inner partitions 16 can be actuated in unison independently of the entire ring of outer partitions 15. The spherical surface portions 17a, 19a, 19b, 24a enable independent rotation of the partitions while maintaining sealing engagement of the respective partitions with the boundary walls.

Referring now to the adjustable exit vanes 13 on the outlet side of the bucket blade portions 9b, vanes 13 are constructed to be adjustable in much the same manner as nozzle partition vanes 15, 16. Each vane 13 is provided with a stem 35 attached thereto and an operating lever 36. Levers 36 of all of the vanes 13 are connected together by means of a ring 37 which can be rotated to simultaneously vary the angles of vanes 13.

An outer circumferential wall 38 provides an arcuate surface upon which the vanes pivot, similar to the wall 17 for partitions 16. An inner circumferential wall is provided by means of arcuate segments 39.

Reference now to FIGS. 2 and 3 of the drawing illustrates the rotating and stationary blade positions for the "forward" turbine and the "reverse" turbine flow paths

respectively. FIG. 2 illustrates the outer flow path, while FIG. 3 illustrates the inner flow path. In both FIGS. 2 and 3, the adjustable vanes are shown in the position they occupy when the load turbine wheel 5 is rotating in the forward or ahead direction. The dotted line positions 13', 15' and 16' indicate the positions of the adjustable vanes after they have been pivoted to the proper position for reverse rotation of turbine wheel 5.

It will be observed from FIG. 3 of the drawing that the inner row of nozzle partition vanes 16 are provided with suitable notches 16a on the backside which are located so that the trailing edges 16b of adjacent nozzle partitions will nest within the notches. This provides a smooth closure wall facing rotating blade portions 9b.

When the turbine wheel 5 is rotating in the forward direction, it will be observed from the solid lines of FIG. 2 that vanes 15 direct the motive fluid at the proper angle into the blade portions 9a of bucket members 9. Reference to FIG. 3 illustrates that at the same time the radially inner nozzle vanes 16 and the adjustable exit vanes 13 are pivoted so as to abut one another on the inlet and outlet sides respectively of reversing blades 9b. During forward operation, vanes 16 and vanes 13 remain in the closed position shown, while the independently functioning nozzle partitions 15 (FIG. 2) can be varied as a group by turning ring 30 to change speed or load of turbine wheel 5.

Vanes 16 and vanes 13 effectively close off the annulus on either side of reversing blades 9b. Together they provide an enclosure which reduces rotation losses when the blades 9b are turning backwardly (as shown in FIG. 3) to a value much less than that which would exist if the exit vanes 13 were not used. Also vanes 13 serve to prevent backward flow of hot exhaust gas from the exhaust hood into the wheel space.

Referring now to the case where reverse operation of turbine wheel 5 is desired, one should refer to the dotted line position of vanes 13, 15 and 16 which are indicated with numerals 13', 15' and 16'. FIG. 2 indicates that vanes 15' abut one another around the entire outer nozzle ring and effectively prevent flow of motive fluid through the forward or outer blade portions 9a. Partitions 15 are not notched since losses in the reverse turbine mode are more acceptable and notching would reduce the efficiency of the vanes.

At the same time, FIG. 3 shows that the vanes 16' and 13' have been rotated to an open position. Vanes 16' can be varied as a group (while vanes 15' remain closed) to control the effective nozzle area and thus the speed or load when the turbine is operating in reverse. The adjustable exit vanes 13' are also open and serve as guide vanes to recover residual whirl energy. These can also be adjusted as a group separate from the other groups during reverse turbine operation to provide the most efficient operating conditions.

While the invention has been described, by way of illustration, using the preferred embodiment of concentric rows of forward and reversing blades on the same turbine wheel, it would be equally applicable to a turbine wheel which had only one row of blades intending for reverse operation only.

It will be apparent to those skilled in the art that various mechanical equivalents of the preferred arrangement shown may be substituted without departing from the scope of the invention. Other modifications will occur to those skilled in the art, and it is desired to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A reversible axial flow turbine comprising:
 - a source of hot motive fluid,
 - a turbine rotor having first and second circumferential rows of blades thereon, the second row comprising

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blades of reverse curvature for effecting rotation opposite that of the first row,
means for selectively admitting motive fluid to the first row of blades for effecting forward rotation of the rotor,

first and second adjustable vane rows disposed on either side of the second blade row, the vanes in each of the rows being pivotable as a group from open to closed position,

whereby both vane rows can either be opened to control motive fluid flow through the second blade row for reverse rotation of the turbine rotor or closed to provide closure walls on the inlet and outlet sides respectively of the second blade row for reducing losses during forward rotation of the turbine rotor.

2. The combination according to claim 1, wherein the first blade row is radially outward of the second blade row on a single turbine wheel, and wherein said means for admitting motive fluid to the first blade row comprises an additional set of adjustable vanes adapted for pivoting as a separate group from open to closed position.

3. The combination according to claim 1, wherein the adjustable vanes in at least one of said rows all define notches therein on the vane backside disposed to receive the trailing edge of an adjacent vane, so as to provide a smooth wall for reducing rotation losses.

4. A reversible axial flow gas turbine comprising:
a source of hot motive fluid,
a turbine wheel having inner and outer concentric circumferential rows of rotating blade portions thereon, the inner row being of reverse blade curva-

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ture for effecting rotation opposite that of the outer row,

a variable area nozzle for each of said rows of rotating blade portions comprising inner and outer concentric circumferential rows of radially extending pivotable vanes,

an exit row of radially extending pivotable vanes disposed on the outlet side of the inner rotating blade row,

means for pivoting the vanes of each of said vane rows as a group separately from any other of said vane rows to selectively provide forward or reverse rotation of said turbine wheel,

whereby the vanes of said inner vane row and said exit vane row can be closed on either side of the inner blade row to reduce rotation losses.

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