Nov. 22, 1966 G. W. SCHEPER, JR 3,286,982

REVERSIBLE AXIAL FLOW GAS TURBINE

Filed Feb. 12, 1965 2 Sheets-Sheet 1

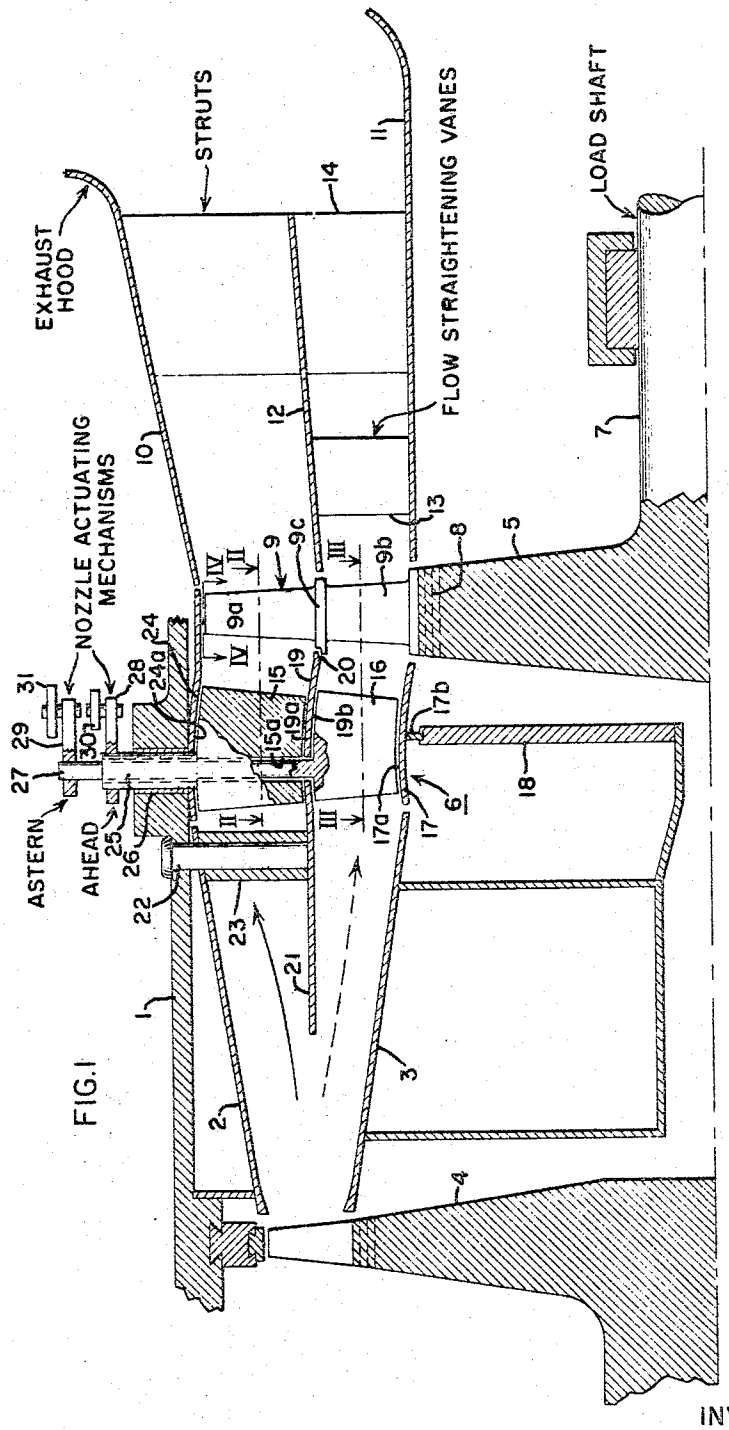


FIG. 1

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FIG.2

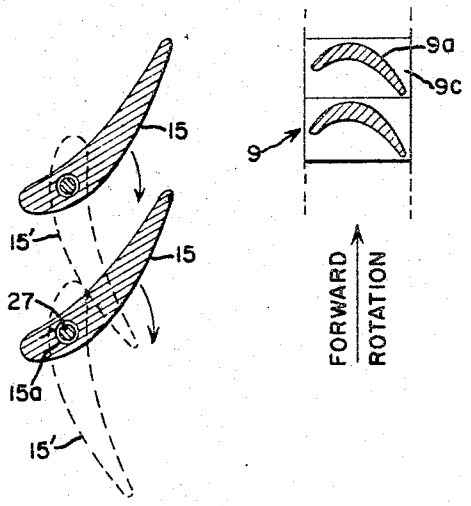


FIG.3

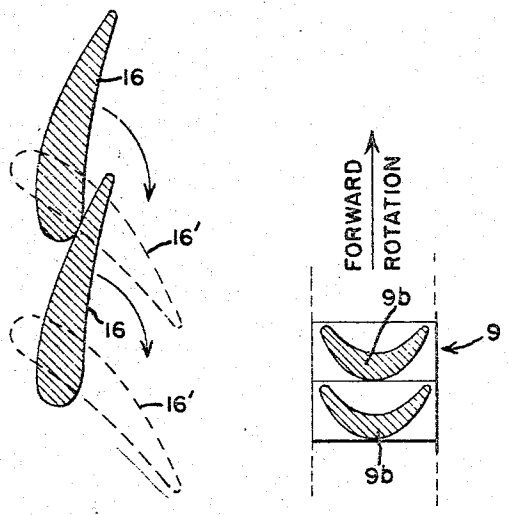
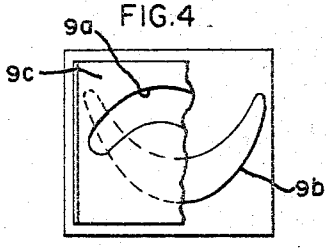


FIG.4



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REVERSIBLE AXIAL FLOW GAS TURBINE

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8 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 nozzle and turbine bucket 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.

There have been suggestions in the literature as to means by which a radial flow gas turbine might be reversed, but by far the greatest number of gas turbines are axial flow and there has been a long-standing problem as to a simple and economical means to provide reversal of the shaft.

Accordingly, one object of the present invention is to provide an improved reversible axial flow gas turbine.

Another object of the invention is to provide an improved gas turbine adjustable nozzle structure for accomplishing shaft reversal in an axial flow gas turbine.

Still another object of the invention is to provide improved gas turbine nozzle and bucket structure with concentric blade rows which provides for reversal and operation of the load shaft at various speeds and loads in an axial flow gas turbine.

Briefly stated, the invention is practiced by providing a gas turbine wheel with two concentric circumferential rows of vanes, one with reverse curvature, and by disposing two concentric rings of radially directed and

pivotable nozzle partitions upstream of the turbine vanes for controlling the flow of motive fluid to one or the other rows of buckets. The nozzle partions for the inner row are actuated by radial stems passing through the partitions for the outer row and through hollow actuating stems for the outer row partitions.

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 vane portion **9***a* shaped to provide forward rotation of the turbine wheel **5** in the usual manner. The radially inner portion is a vane portion **9***b* with reverse curvature to provide astern operation or reverse rotation of wheel **5**. Vane portions **9***a*, **9***b* are separated by an intermediate platform portion **9***c* 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 foil sections **9***a*, **9***b*.

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 flow straightening vanes **13** and supporting struts **14** is also 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 **15** arranged to direct motive fluid into the outer ring of turbine vane portions **9***a*. Radially inward from and concentric with partitions **15** is an inner circumferential row of radially directed and movable nozzle partitions **16**.

The radially innermost boundary for the motive fluid is provided by means of an annular member **17** having an outer surface **17***a* which is a portion of a sphere and having an inner flange **17***b* 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** which spherical sur-

faces on its upper and lower sides at 19*a* and 19*b* respectively. Member 19 has a suitable sealing lip 20 cooperating with the platforms 9*c* 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 24*a*. The center of curvature for all of the spherical surfaces 17*a*, 19*a*, 19*b*, and 17*a* 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 15*a* 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 26 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 26, 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 17*a*, 19*a*, 19*b*, 24*a* enable independent rotation of the partitions while maintaining sealing engagement of the respective partitions with the boundary walls.

Reference to FIGS. 2 and 3 of the drawing illustrates the nozzle and bucket stages for the "forward" turbine and the "reverse" turbine flow path respectively. In both FIGS. 2 and 3, the partitions 15 and 16 are shown in solid lines in the position they occupy when the load turbine wheel 5 is rotating in the forward or ahead direction. The dotted line positions 15′ and 16′ indicate the positions of the same partitions after they have been rotated to the proper position for astern operation or reverse rotation of turbine wheel 5.

When the turbine wheel 5 is rotating in the forward direction, it will be observed from the solid lines of FIG. 2 that partitions 15 direct motive fluid at the proper angle into the vane portions 9*a* of bucket members 9. Reference to FIG. 3 illustrates that at the same time, the radially inner nozzle partitions 16 have been pivoted to abut one another around the entire inner flow annulus and thus effectively block flow of motive fluid into the radially inner vane portions 9*b* of bucket members 9. It will be observed that during forward operation, due to the ability of inner and outer partitions to move independently of one another, partitions 15 can be varied as necessary by the operating ring 30 to change speed or load of turbine wheel 5, while the partitions 16 remain in the blocking position shown in FIG. 3.

It should be particularly noted that during forward rotation as described, the vane portions 9*b* are turning in an opposite direction from that which would be normal for a turbine bucket. This would lead to large losses if it were not for the fact that the pivoted nozzle partitions present a relatively smooth wall to effectively reduce these losses to a minimum. Previous suggestions for concentric reversing buckets in steam turbines have not overcome this problem due to the employment of "fixed" nozzle partitions.

Referring now to the case where reverse operation of turbine wheel 5 is desired, it is necessary to refer to the dotted line position of the partitions in FIGS. 2 and 3 shown as 15′ and 16′. FIG. 2 indicates that partitions 15′ abut one another around the outer nozzle ring and effectively prevent flow of motive fluid against the curved vaned portions 9*a* of buckets 9. As discussed above, rotation losses of the reverse-turning vanes 9*a* are reduced by the wall of partitions 15. At the same time, FIG. 3 shows that partitions 16′ have been rotated to an open position and can control the effective nozzle area available for the inner path of gas against the curved vane portions 9*b* of the buckets.

Thus the invention described provides a simple means for reversing an axial flow gas turbine. It will, of course, be apparent to those skilled in the art that various mechanical arrangements to provide proper sealing and cooling of the nozzle partitions are desirable. These have been omitted in order not to obscure the present 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 gas turbine comprising:
   a source of hot motive fluid,
   a turbine wheel having two concentric circumferential rows of vanes thereon, one of the rows being of reverse blade curvature for effecting rotation opposite that of the other row, and
   a variable area nozzle for each of said rows of vanes comprising two concentric circumferential rows of radially extending pivotable nozzle partitions, the partitions in each row being pivotable as a group separately from the partitions in the other row from open to closed position, and
   means for separately pivoting said nozzle partition rows to selectively provide forward or reverse rotation of said turbine wheel.

2. The combination according to claim 1, wherein each partition of one row of nozzle partitions is actuated by a radial stem passing through a partition in the other row of partitions.

3. A reversible axial flow gas turbine comprising:
   gas generator means supplying hot motive fluid through a turbine casing,
   a turbine wheel having buckets thereon each including inner and outer vanes separated by platform portions to provide inner and outer concentric rows of vanes, the inner vanes being curved oppositely from the outer vanes to provide for reverse rotation of the wheel,
   inner and outer concentric circumferential rows of radially directed inner and outer nozzle partitions arranged to direct motive fluid toward the inner and outer turbine vanes respectively, said outer partitions defining radial openings therethrough and including hollow first radial actuating stems attached thereto, said inner partitions including second radial actuating stems attached thereto extending through said outer partition openings and through said hollow first radia stems.

4. The combination according to claim 3 including first, second and third annular concentric members defining sealing surfaces thereon arranged to sealingly engage the inner and outer partitions as they are actuated separately from one another, said sealing surfaces having curvatures derived from spherical portions having a common center of curvature on the turbine wheel axis.

5. The combination according to claim 3, including first means to actuate the outer partitions as a group from open to abutting position, and second means to separately actuate the inner partitions as a group from open to abutting position, whereby the outer partitions may be

opened to effect control of motive fluid to the outer turbine stage while the inner partitions may be left closed to block fluid and to reduce rotation losses due to the reverse curved inner turbine stages, and vice versa.

6. The combination according to claim 3, wherein said gas generator means includes a second independently rotatable turbine wheel discharging hot motive fluid toward said concentric rows of nozzle partitions and wherein there is provided an annular flow guiding duct extending between the second turbine wheel and said partitions and having an intermediate annular flow dividing member therein, said flow dividing member terminating in an annular dividing wall portion disposed between inner and outer partition rows and defining inner and outer spherical sealing surfaces arranged to cooperate with the inner and outer nozzle partitions.

7. The method of operating an axial flow reversible gas turbine, comprising the steps of:

providing a turbine wheel with outer and inner forward and reversing turbine stages respectively,

providing inner and outer concentric circumferential rows of separately pivotable radial nozzle partitions,

closing one row of nozzle partitions by pivoting them to abutting position to block motive fluid flow there-

through and present a relatively smoth wall to reduce rotation losses, and

actuating the other row of nozzle partitions in partially open or full open position to effect operation of the turbine wheel at a desired speed or load.

8. The method according to claim 7 including the additional step of reversing rotation of the turbine wheel by closing the aforesaid open row of nozzle partitions and opening the aforesaid closed row of nozzle partitions.

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