Jan. 6, 1953 D. J. BLOOMBERG 2,624,173

HEAT INSULATING ARRANGEMENT FOR A PLURALITY OF COAXIAL TURBINES HAVING OPPOSED FLOW THROUGH DOUBLE-TIER BLADING

Filed Oct. 31, 1950 2 SHEETS—SHEET 1

Fig.1.

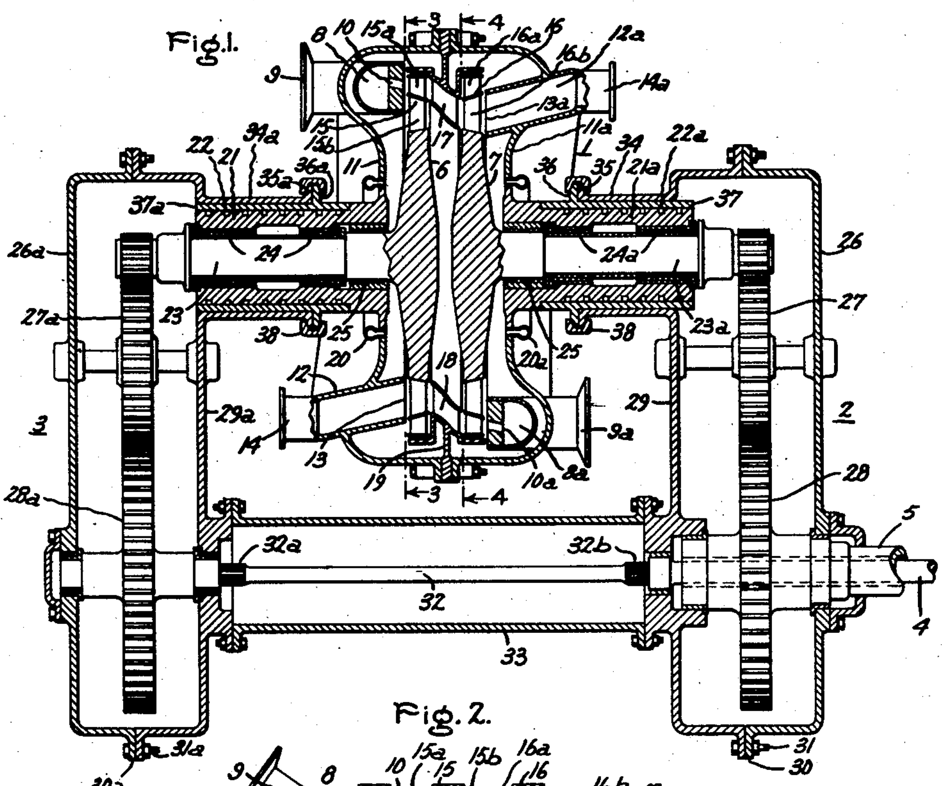

Fig.2.

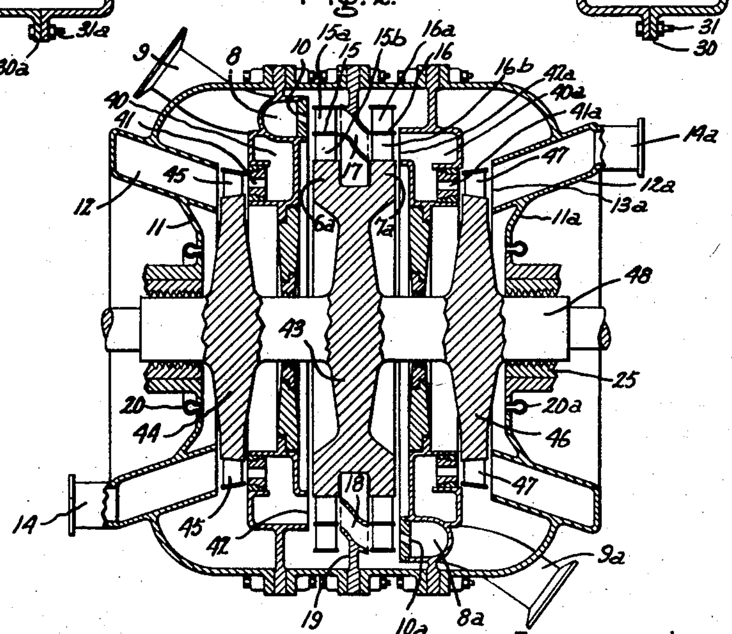

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Fig. 3.

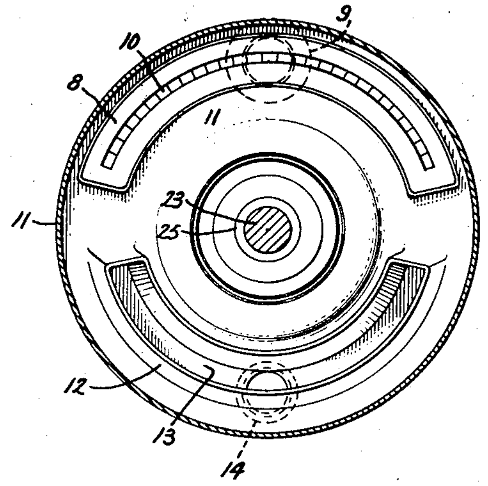
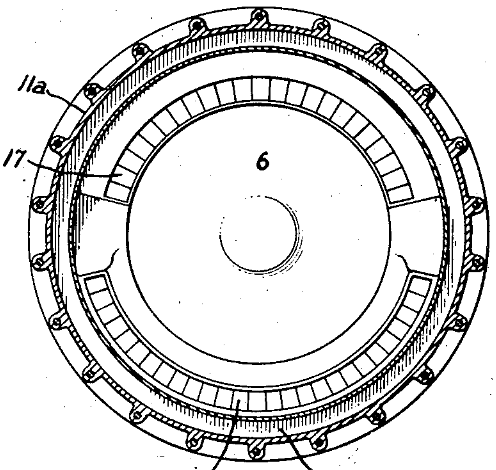


Fig. 4.



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HEAT INSULATING ARRANGEMENT FOR A PLURALITY OF COAXIAL TURBINES HAVING OPPOSED FLOW THROUGH DOUBLE-TIER BLADING

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12 Claims. (Cl. 60—49)

1

The present invention relates to fluid pressure energy converting devices and more particularly to an improved turbine arrangement.

My improved turbine arrangement is particularly useful as an energy converting device for the propulsion of aircraft or torpedoes, and is provided with features that are desirable and often necessary in other applications where self-oxidizing fuels, high temperature, and high degree of energy conversion are of importance. Among such uses to which my invention is particularly suited are special reversing turbines for marine applications, generator drives for high altitude aircraft, and high capacity fuel pump drives for rockets, etc.

An object of the invention is to provide an improved turbine arrangement.

Another object of the invention is in the provision of a turbine having substantially balanced torque reaction or in which torque unbalance is substantially minimized.

Another object is in the provision of an improved turbine arrangement which is capable of converting large amounts of energy with turbine parts of minimum size and weight.

Still another object of the invention is in the provision of an improved turbine flow path for producing greater output and with improved efficiency.

Still another object is in the provision of an improved flow path arrangement that permits the use of higher operating temperatures than was previously possible.

Other objects and advantages will be apparent from the following description taken in connection with the accompanying drawings, in which Fig. 1 is a view, partly in section, illustrating one embodiment of the invention; Fig. 2 is another sectional view showing a modified embodiment of the invention; Fig. 3 is a view showing the combined nozzle ring and casing structure of the arrangement shown in Fig. 1 (looking in the direction of the arrows 3—3) with the turbine rotor removed; and Fig. 4 is a view looking in the direction of arrows 4—4 in Fig. 1 showing the intermediate passage portions.

Referring to Fig. 1, my improved energy converting apparatus, including a turbine, indicated generally at 1, and gearing, indicated generally at 2 and 3, is connected to and arranged to supply power to contra-rotating shafts 4, 5 which are connected to any desired type of power consuming apparatus (not shown). A feature of the invention is in the provision of turbine apparatus having contra-rotating mechanically independent rotors 6, 7 each arranged to convert equal amounts of energy from motive fluid supplied to the turbine and to deliver the energy so converted to contra-rotating shafts 4, 5, respectively, so that there is substantially no resultant torque reaction therefrom.

2

Motive fluid under pressure and at elevated temperature is supplied to independent nozzle boxes 8, 8*a* provided with inlet ports 9, 9*a*, respectively. The apparatus utilized for producing the motive fluid forms no part of the present invention and is therefore not shown. It will be understood by those skilled in the art that the motive fluid may be supplied by any well known type of gas generating apparatus, combustion apparatus, or may be supplied by chemical reaction.

Nozzle boxes 8, 8*a* are identical for all practical purposes and, as will be apparent by reference to Fig. 1, are angularly displaced from each other by approximately 180°. Suitably secured to the walls of each nozzle box are nozzle portions 10, 10*a*, respectively, for expanding the motive fluid to a high velocity and for directing the motive fluid at a desired angle with respect to the turbine rotors 6, 7.

Referring now to Figs. 1 and 3, the nozzle boxes 8, 8*a* and the corresponding rings of nozzles 10, 10*a*, respectively, extend through an arc of approximately 160° or less and are displaced from each other by 180°.

Still referring to Figs. 1 and 3, nozzle box 8, inlet connection 9 and nozzles 10 are carried by a casing member 11 which also carries an exhaust collector portion 12. Exhaust collector portion 12 is provided with an arcuate opening 13 which is angularly displaced from nozzles 10 by 180°. Arcuate opening 13 admits motive fluid discharged from turbine rotor 6 into exhaust collector 12 and, as indicated in Fig. 3, opening 13 extends through approximately 160° of arc or some smaller amount. Exhaust collector 12 is also provided with a discharge connection 14 having a suitable opening therein for discharging motive fluid directly to the atmosphere or, if desired, for connection to a suitable exhaust conduit (not shown) for conveying exhaust motive fluid away from the turbine 1.

In a similar manner, casing member 11*a* carries nozzle box 8*a*, inlet connection 9*a*, and nozzles 10*a* all disposed in a similar manner with respect to an exhaust collector 12*a* having a similar opening 13*a* and exhaust connection 14*a*.

Another important feature of the invention is in the provision of two independent and concentric flow paths on each of the rotors 6 and 7. This is accomplished by the provision of a plurality of turbine buckets 15 secured to rotor 6 and disposed to define independent flow paths 15a and 15b therethrough. A plurality of buckets 16 similarly disposed to define independent paths 16a and 16b are carried by rotor 7. Buckets 15 and 16 are identical except that they are so arranged that rotors 6 and 7 will rotate in opposite directions.

Referring now to Figs. 1 and 4, intermediate passage portions 17 and 18 angularly displaced from each other by 180° are provided for transferring flow from bucket portions 15a to bucket portions 16b and from bucket portions 16a, to bucket portions 15b, respectively.

As clearly indicated in Fig. 4, passage portions 17 and 18 are arcuate portions each of which extends through approximately 160° of arc. Passage portions 17 and 18 are carried by an intermediate structural member 19 which is in turn supported by casing members 11, 11a in a manner which will be apparent from Fig. 1.

Thus it will be apparent that two independent flow paths are provided through the turbine portion of the apparatus and since inlet connections 9 and 9a are each connected to the same source of motive fluid and buckets 15 and 16 are identical except with respect to direction of rotation, each rotor will produce equal power output at all operating conditions thereby insuring balanced torque on the turbine casing. The first flow path is defined by nozzle box 8, nozzles 10, bucket portions 15a, intermediate passage portion 17, bucket portions 16b, exhaust collector 12a, and the fluid is finally discharged through exhaust connection 14a. The other flow path is from nozzle box 8a, nozzles 10a, bucket portions 16a, intermediate passage portion 18, bucket portions 15b, exhaust collector 12 and the motive fluid is finally discharged from exhaust connection 14.

The initial portion of each flow path is arranged to produce an axially inward direction of gas flow; that is, nozzle 10, bucket portions 15a, intermediate passage 17, as well as nozzles 10a, bucket passages 16a and intermediate passage 18, each produce an axially inward flow from the upper flow passageway of one rotor to the lower passageway of the opposite rotor. Those skilled in the art will appreciate that the arrangement described has another important advantage in that the outer bucket flow path receives motive fluid from nozzles 10 and the innermost bucket flow path handles gases only after they have been expanded through one of the turbine rotors 6, 7. The expansion process removes considerable energy from the motive fluid. This means that the relatively low stressed portions of the buckets, that is, portions 15a, 16a, handle high temperature motive fluid, and that the more highly stressed portions of the buckets 15b, 16b handle motive fluid at a reduced temperature. It will also be appreciated that the provision of dual opposed rotors will permit a lower rotational speed than that of a corresponding single stage turbine designed to convert the same amounts of energy with the same wheel diameter. This lower rotational speed permits the use of the longer buckets as described herein without increasing bucket stresses beyond safe values. Furthermore, the lower rotational speed permits a lighter wheel and is more favorable to the problems connected with bearing design, design of seals, and critical speed problems.

Each casing portion 11, 11a is provided with a concentric expansion joint 20, 20a joining the casing walls with the bearing housings 21, 21a, respectively. Bearing housings 21, 21a are coaxial axially extending cylindrical portions having a plurality of axially spaced circumferentially extending grooves provided therein at the outer surface. Secured to rotors 6, 7 are shafts 23, 23a, respectively, which are rotatably supported by bearings 24, 24a, provided in housings 21 and 21a, respectively. A suitable seal 25 is provided between bearings 24 and rotor 6 and between bearings 24a and rotor 7 to minimize any tendency for motive fluid to leak along the shafts 23, 23a and ultimately mix with lubricant supplied to the bearings, or to minimize any tendency for lubricant to leak past the bearings and along shafts 23, 23a into the turbine casings 11, 11a.

Gearing 2, 3 is provided with casings 26, 26a which enclose and rotatably support gears 27, 28 and 27a, 28a, respectively. As illustrated in Fig. 1, gear casings 26, 26a are made in two pieces to facilitate inspection, assembly and disassembly. Wall portions of the casing members are provided with flanged joints 30 and 30a for securing the two casing halves together by threaded fastenings 31, 31a. Casing walls 26 and 29, and 26a and 29a rotatably support gears 27, 27a, 28, 28a and shaft 4 is connected to gear 28a by an intermediate shaft portion 32 having splined end portions 32a and 32b in a manner which will be apparent by reference to Fig. 1. In order to provide stiffness and maintain proper alignment of gearing 2 and 3, as well as for safety reasons, intermediate shaft portion 32 is enclosed by a cylindrical casing member 33 secured to casing walls 29, 29a.

Casing wall portions 29, 29a are provided with coaxial cylindrical portions 34, 34a extending toward turbine casings 11a, 11, respectively. At the respective ends of cylindrical portions 34, 34a are provided flanges 35, 35a, respectively, for connection to corresponding flanges 36, 36a of sleeves 37, 37a. Sleeves 37, 37a have an inner cylindrical surface that fits tightly against the outer cylindrical surfaces between grooves 22, 22a of bearing housings 21, 21a. The outer cylindrical surfaces of sleeves 37, 37a are so proportioned as to perform a relatively close push fit with the inner surfaces of cylindrical portions 34, 34a. Clamps 38, which may be of the "quick disconnect" type as described in Patent 2,424,436, issued to Crater, assigned to the assignee of the present application, are provided for securing flanges 35, 36 and 35a, 36a together. It will be appreciated that such an arrangement provides ease of assembly or disassembly for the removal or assembly of gear casings 26, 26a with respect to turbine casings 11, 11a. At the same time the tightly fitting surfaces of sleeves 37, 37a and bearing housings 21, 21a and the cooperating grooves 22, 22a provide an effective seal against the outward leakage of lubricant from the interior of gear casings 26, 26a.

In operation, motive fluid is supplied to inlet connection 9 and nozzle box 8 under pressure and at elevated temperatures. The motive fluid is expanded through nozzles 10 thereby increasing the velocity of motive fluid and at the same time reducing its pressure and temperature. Nozzles 10 also direct the motive fluid at high velocity at the proper angle with respect to turbine bucket portions 15a thereby causing rotor 6 to rotate and convert a portion of the energy contained in the motive fluid into mechanical power which is supplied to shaft 4 through turbine shaft 23, intermediate shaft 32 and connected gearing 3. Fluid discharged from turbine buckets 15a then flows through intermediate portion 17 and into turbine buckets 16b causing rotor 7 to turn in a direction opposite to that of rotor 6. Rotor 7 thereby converts an additional portion of the energy contained in the motive fluid into mechanical power which is supplied to shaft 5 through rotor shaft 23a and connecting gearing 2. In a like manner motive fluid is supplied to inlet connection 9a, nozzle box 8a, nozzles 10a, from which it flows through bucket portions 16a, intermediate passageway 18 and bucket passages 15b with a portion of the energy contained in the motive fluid being converted by each of rotors 6 and 7 and ultimately delivered as useful power to shafts 4 and 5, respectively.

As already indicated, inlet connections 9, 9a are connected to the same source of motive fluid and since the flow path through each rotor is substantially identical, each rotor will produce equal power output at all operating conditions thus insuring a substantially balanced torque reaction on the turbine casing. Fluid discharged from turbine buckets 15b, 16b is received in exhaust collector passages 12, 12a, respectively, and is ultimately discharged through exhaust connections 14 and 14a, respectively.

Both rotors 6, 7 receive motive fluid from nozzles 10, 10a into the passages defined between adjacent bucket portions 15a, 16a, respectively. The motive fluid as it leaves the nozzles is at its maximum temperature as far as the turbine rotor is concerned, and thus it will be seen that this high temperature portion of the motive fluid is handled entirely by bucket portions 15a and 16a. After the motive fluid has passed through the passages defined by these bucket portions, the pressure and temperature of the motive fluid is considerably reduced. Bucket portions 15b and 16b handle motive fluid only at reduced temperatures. Thus it will be seen that operating temperature of the outer bucket flow path, that is, bucket passages 15a, 16a is highest where the stresses due to rotation of the rotor are considerably lower than the stresses that exist in bucket portions 15b, 16b which handle only fluid at a lower temperature.

Fig. 2 shows a modified embodiment of the invention permitting the use of higher temperatures or higher pressures of the motive fluid at the turbine inlets. Such an arrangement provides improved efficiency and, for a given physical size, increased output. Like elements employ the same notations as used in Fig. 1.

The arrangement shown in Fig. 2 differs from that of Fig. 1 in two major respects. First, after passing through the inner and outer bucket passage portions 15a, 16a, 15b, 16b, the motive fluid is subsequently expanded through additional sets of nozzles and buckets. In addition, the various turbine rotors rotate in a common direction and are secured to a single common shaft.

Nozzle box 8, inlet connection 9 and nozzles 10 are as described in connection with Fig. 1 and in addition a second and independent chamber 40 having a second set of nozzles 41 and an inlet opening 42 is carried by nozzle box 8. For reasons previously discussed in connection with opening 13 in Fig. 1, opening 42 is arcuate in shape, extends through approximately 160° of arc or less and is displaced from nozzles 10 by 180°. A similar chamber 40a comprising nozzles 41a and opening 42a is carried by and is similarly disposed with respect to nozzle box 8a. As is clearly indicated, nozzles 10 and 10a are disposed adjacent to bucket portions 15a and 16a respectively. Openings 42 and 42a are disposed adjacent to bucket portions 15b, 16b, respectively, for receiving motive fluid discharged therefrom. As indicated in the drawing, nozzles 41 and 41a extend through 360°, or full arc admission is employed. If desired, nozzles 41 and 41a can be arranged for partial arc admission. It will be understood by those skilled in the art that partial arc admission means that nozzles 41 and 41a extend through an arcuate opening of something less than 360°. If partial arc admission is employed, the disposition of arcuate nozzle portions 41 and 41a with respect to arcuate openings 42, 42a, respectively, is not critical.

Still referring to Fig. 2, intermediate section 19 carrying passage portions 17, 18 is similar to the arrangement described in connection with Fig. 1 and differs therefrom only in that the intermediate flow path portions 17, 18 of Fig. 2 reverse the direction of flow therethrough because all rotor portions in Fig. 2 rotate in the same direction. Rotor 43, rotor 44 carrying buckets 45, and rotor 46 carrying buckets 47 are carried by a common shaft, and therefore all rotate in the same direction. Rotor 43 has separate rotor portions 6a and 7a carrying buckets 15, 16, respectively.

In operation, motive fluid under pressure is supplied from a suitable source (not shown) to inlet connections 9, 9a, respectively. From inlet connection 9 the motive fluid flows into nozzle box 8 and is expanded by nozzles 10, thereby reducing its pressure and temperature and at the same time increasing the velocity thereof. The motive fluid at high velocity is then directed into bucket portions 15a which convert a portion of the fluid energy into mechanical energy for causing rotation of rotor 43 and shaft 48. The motive fluid is discharged from bucket portions 15a into intermediate passage portion 17 which, as previously indicated, reverses the direction of flow thereof and discharges the fluid into bucket portions 16b thus converting an additional portion of fluid energy under mechanical energy. As the fluid is discharged from bucket portion 16b, it is received into the nozzle box 40a through arcuate opening 42a. The fluid is then expanded through nozzles 41a thereby reducing its pressure and temperature still further. It is then discharged into buckets 47 for the additional conversion of fluid energy into mechanical energy for driving rotor 46 and shaft 48. The motive fluid is then discharged from buckets 47 through opening 13a into exhaust collector 12a from which it is discharged through opening 14a in the manner described in connection with Fig. 1 above. The motive fluid delivered to inlet connection 9a passes in a similar manner through nozzle box 8a, nozzles 10a, bucket passages 16a, intermediate passage portion 18, buckets 15b, arcuate opening 42, nozzle box 40, nozzles 41, buckets 45, through opening 13 into exhaust collector 12 and discharge opening 14 to convert additional portions of fluid energy into mechanical energy for driving rotor 43, rotor 44 and shaft 48.

Thus it will be seen that the temperature of the motive fluid flowing through the innermost bucket flow passages, that is, bucket portions 15b, 16b is considerably reduced in value as compared to the temperature of the motive fluid at the inlet or in nozzle box 8 and because of the energy converted by bucket portions 15a, 16a. Since the outer portions 15a, 16a of buckets 15, 16 respectively, are the lowest stressed portions of the bucket, my improved turbine arrangement will permit the use of higher temperature motive fluid than was heretofore possible. It will also be appreciated by those skilled in the art that the use of an increased temperature at the inlet to an energy converting device results in improved thermal efficiency. In addition, my improved turbine arrangement provides a rotor structure wherein the innermost portion of the bucket flow path, that is, bucket portions 15b, 16b will operate at a lower temperature than conventional turbine arrangements employing motive fluid at the same inlet temperatures, thus permitting higher allowable stresses in the innermost bucket portions. An additional and important advantage of the lower temperature of the motive fluid in the innermost portion of the bucket flow path is that my improved arrangement reduces the thermal strain or temperature gradient which may be imposed upon a turbine rotor under emergency operating conditions.

It will also be recognized that the two row rotor arrangement can be used as the first stage of a double flow turbine, as illustrated in Fig. 2, or the motive fluid discharged from the respective sides of the two row wheel can be conveyed into a single receiver and then either exhausted or fed into other turbine stages for further expansion.

While particular embodiments of the invention have been illustrated and described, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from the invention and it is intended to cover in the appended claims all such changes and modifications as come 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 fluid pressure energy converting device comprising walls defining a pair of independent inlet fluid passageways having axially spaced end portions, first and second rows of moving blades disposed between said end portions and each of said rows forming separate inner and outer concentric fluid passageways, said outer passageways being disposed adjacent to said end portions for receiving fluid discharged therefrom, and walls defining two independent arcuate fluid passageways between said rows of moving blades establishing a connecting flow path between the outer concentric passageway of said first row of blades and the inner concentric passageway of said second row and between said outer passageway of said second row and said inner passageway of the first row of moving blades.

2. Apparatus in accordance with claim 1 wherein said arcuate passageways are oppositely disposed and each arcuate passageway extends through an arc of less than 180°.

3. Apparatus in accordance with claim 1 wherein said arcuate passageways are angularly spaced by 180° and each arcuate passageway extends through an arc less than 160°.

4. A turbine apparatus comprising a pair of casing members each having an inlet connection in communication with nozzle means and having an exhaust connection in communication with a fluid passageway within said member, a rotor, at least two rows of blading carried by said rotor, each row of blading having separate inner and outer concentric fluid passages, one of said rows of blading being disposed with its outer fluid passage adjacent to the nozzle means associated with the first of said pair of casing members and with its inner passage adjacent to the fluid passageway associated with said first casing member,

the second casing member and second row of blading being similarly arranged, first walls defining an arcuate flow passage portion and establishing communication between said outer passage of said first row of blading and the inner passage of said second row of blading, and second walls defining an arcuate flow passage portion establishing communication between the outer passage of said second row of blading and said inner passage of said first row of blading.

5. Apparatus in accordance with claim 4 wherein said nozzle means, said casing passageway, and said arcuate passage portions defined by said first and second walls extend through arcs less than 160°; the nozzle means associated with the first casing member, the outer concentric passage of the first row of blading, the arcuate passage portion defined by said first walls, and the passageway associated with the second casing member are disposed in substantial alignment to form a first flow path extending in a generally axial direction; the nozzle means associated with the second casing member, the outer concentric passage of the second row of blading, said arcuate passage portion defined by said second walls and the passageway associated with the first casing member being disposed in substantial alignment to form a second flow path extending in a generally axial direction and angularly spaced from the first flow path.

6. A turbine apparatus comprising a pair of casing members each having an inlet connection in communication with nozzle means within said members and having an exhaust passageway therein, first and second rotors carrying a double tier row of blading each forming separate concentric inner and outer fluid passages, each of said rotors being rotatably supported in one of said casing members with its outer concentric passage adjacent to the nozzle means associated with one of said casing members for receiving motive fluid issuing from said nozzle means and with its inner concentric passage adjacent to the exhaust passageway associated with said one casing member for discharging motive fluid into said passageway, walls defining a first arcuate fluid passage portion between the blading carried by said rotors and communicating with the outer concentric passage carried by the first rotor and with the inner concentric passage carried by the second rotor, and other walls defining a second arcuate fluid passage portion between the blading carried by said rotors and communicating with the outer concentric passage carried by the second rotor and with the inner concentric passage carried by the first rotor.

7. Apparatus in accordance with claim 6 wherein the nozzles associated with the first casing member, the outer concentric passage carried by the first rotor, said first arcuate passage portion, the inner concentric passage carried by the second rotor, and the exhaust passageway associated with the second casing member are disposed in substantial alignment to form a first flow path, and the nozzle means associated with the second casing member, the outer concentric passage carried by the second rotor, said second arcuate passage portion, the inner concentric passage defined by the blading carried by the first rotor, and the exhaust passageway associated with the first casing member are disposed in substantial alignment to form a second flow path.

8. Apparatus in accordance with claim 7 wherein said rotors rotate in opposite directions.

9. Apparatus in accordance with claim 8

wherein said first and second arcuate passage portions extend through an arc less than 160°.

10. Apparatus in accordance with claim 8 wherein said nozzle means, said exhaust passageways, and said first and second arcuate passage portions extend through arcs less than 160° and said first and second flow paths are angularly displaced by substantially 180°.

11. Apparatus in accordance with claim 10 and including a pair of coaxial output shafts, gearing connecting the first rotor to one of said shafts, and other gearing connecting the second rotor to the other of said shafts.

12. Apparatus in accordance with claim 11 wherein said coaxial shafts rotate in opposite directions.

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