Sept. 19, 1961 J. LISTON 3,000,611

REVERSIBLE TURBINE

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Fig. 1.

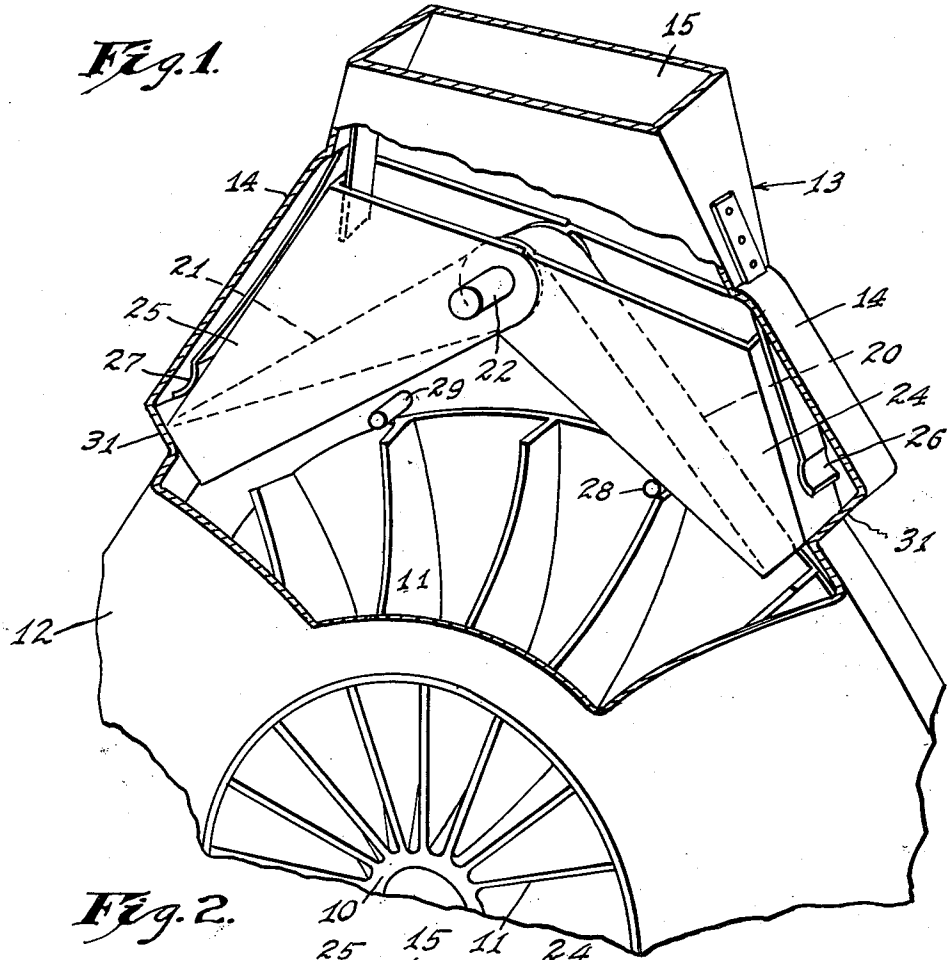
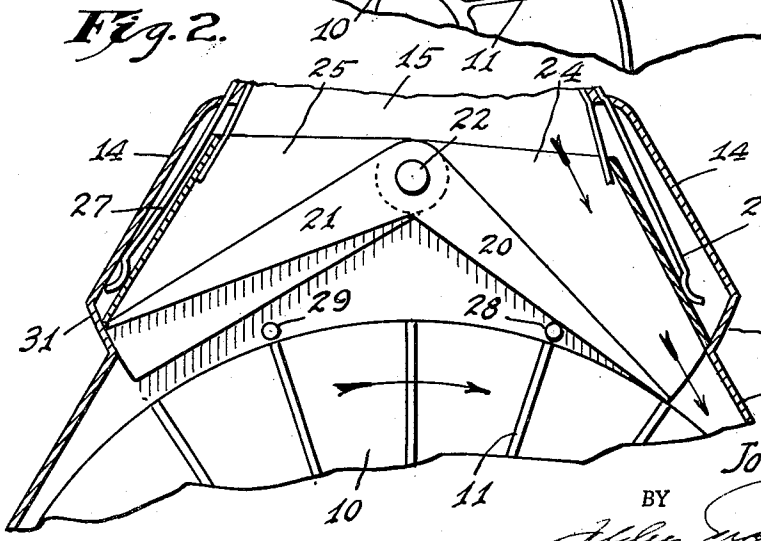


Fig. 2.



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Sept. 19, 1961 J. LISTON 3,000,611

REVERSIBLE TURBINE

Filed Oct. 14, 1957 4 Sheets-Sheet 2

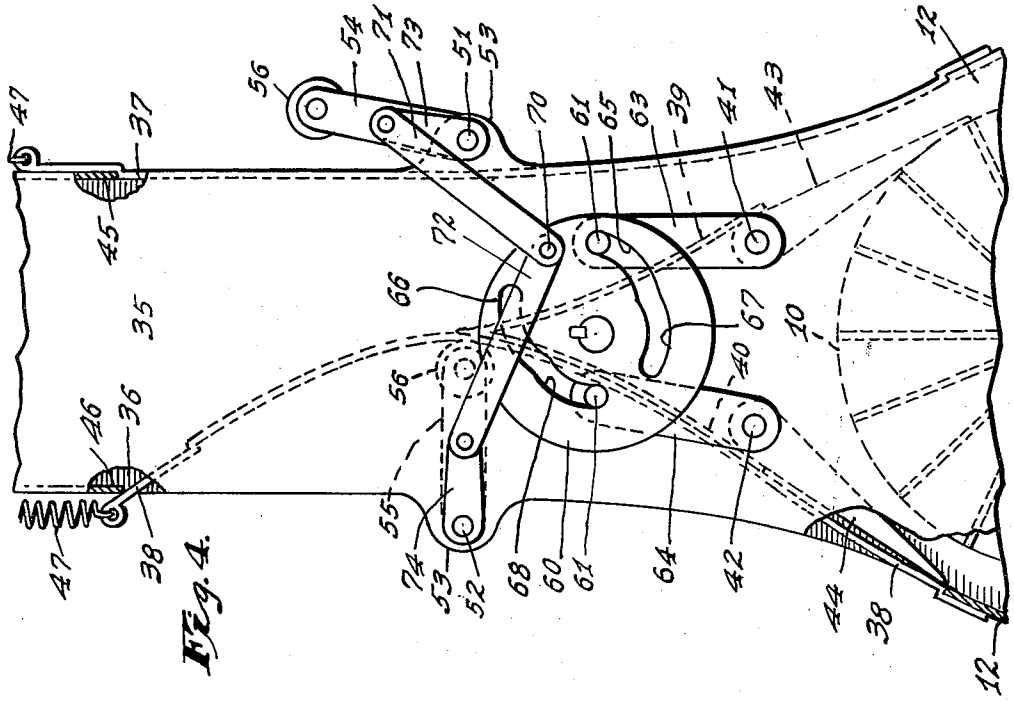


Fig. 4.

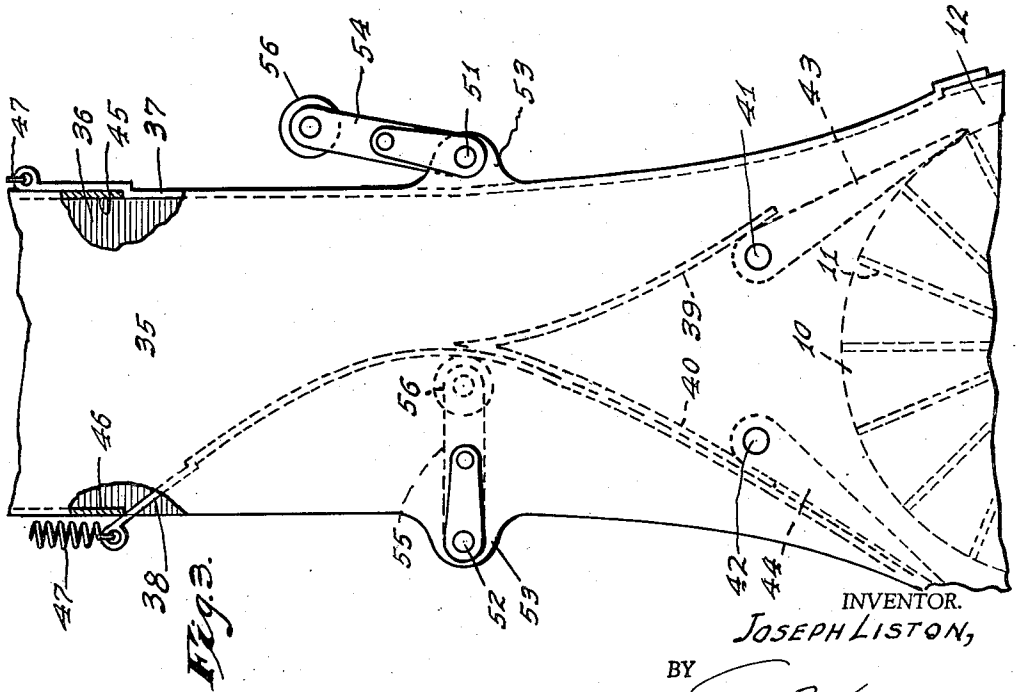


Fig. 3.

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Sept. 19, 1961 J. LISTON 3,000,611

REVERSIBLE TURBINE

Filed Oct. 14, 1957 4 Sheets-Sheet 3

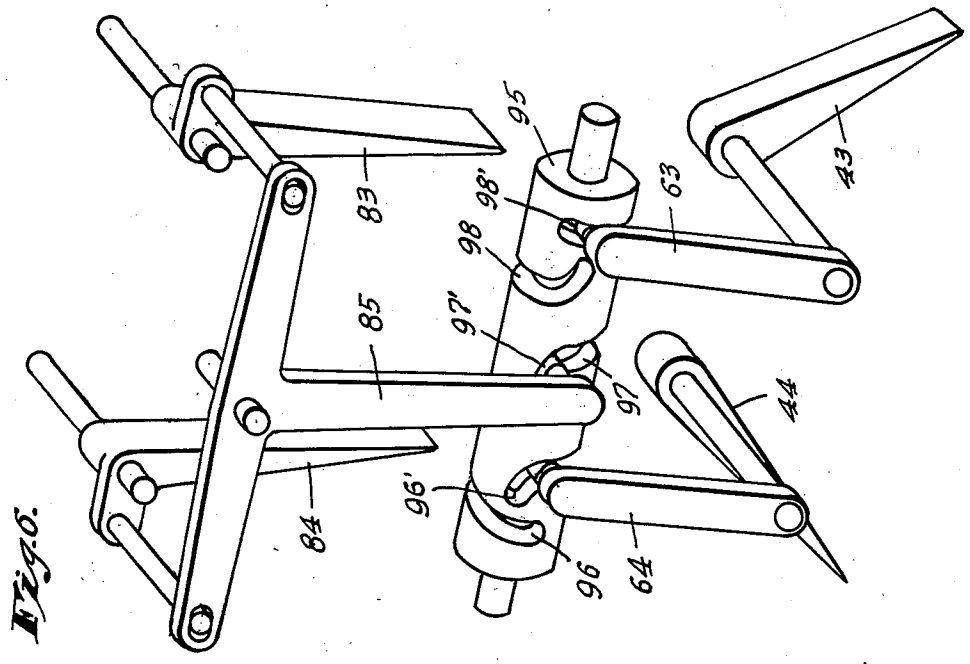


Fig. 6.

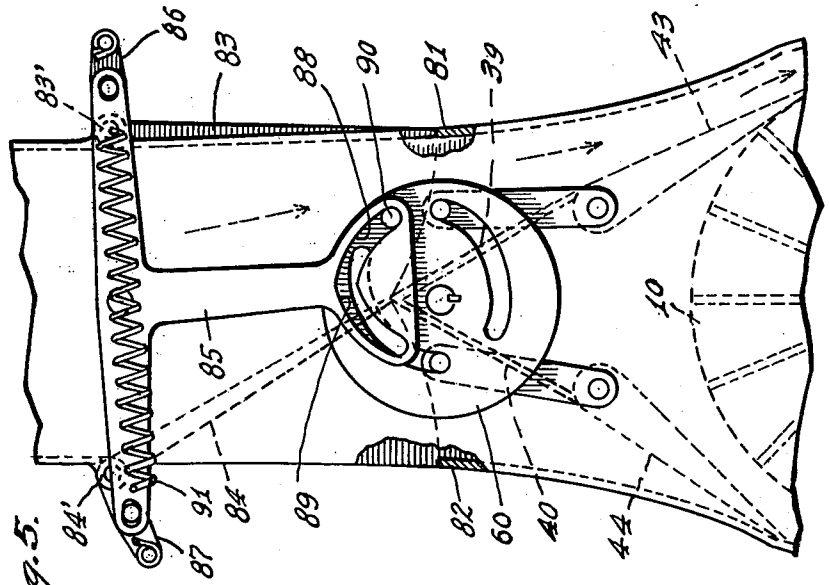


Fig. 5.

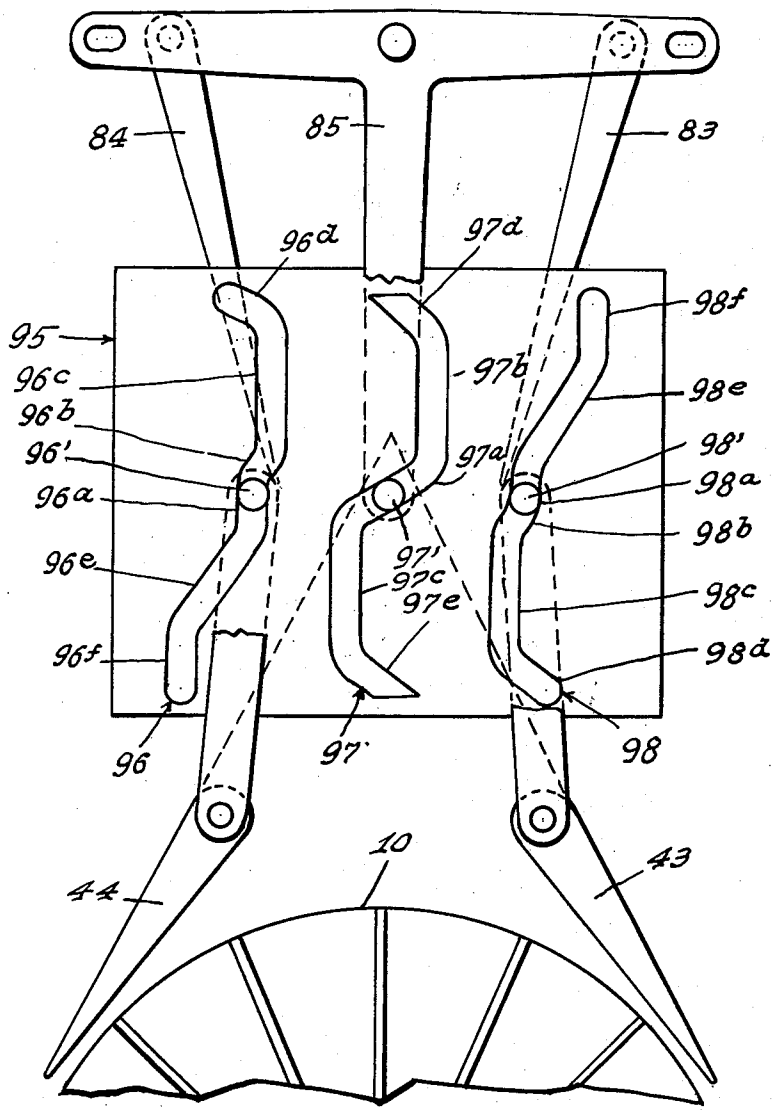
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REVERSIBLE TURBINE

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Fig. 7.



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3,000,611
REVERSIBLE TURBINE

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Filed Oct. 14, 1957, Ser. No. 690,037
10 Claims. (Cl. 253—51)

This invention relates to gas turbines and more especially to reversible turbines and control means therefor.

In carrying out the invention in its preferred form, I employ a turbine of the radial-flow type. The turbine-housing has an inlet opening receiving gas from a supply conduit, and associated with such inlet openings are means by which the entering gas can be controlled with respect both to its rate of flow and to the tangential direction in which it discharges against the blades of the turbine rotor. Such flow-controlling means is designed to minimize resistance to movement of the gas in order to eliminate as far as possible energy losses which would result from abrupt changes in the direction or cross-sectional area of the gas passage. Means may be provided for jointly regulating both the aforesaid flow-controlling means and the source for the gas used by the turbine.

In the accompanying drawings, which illustrate the invention:

FIG. 1 is a fragmental isometric view of a turbine with portions of the housing broken away;

FIG. 2 is a fragmental cross-section of the turbine shown in FIG. 1;

FIG. 3 is an elevational view, partially broken away, showing a modified form of flow-controlling means;

FIG. 4 is an elevational view showing operating mechanism for the device of FIG. 3;

FIG. 5 is an elevation showing still another form of flow-controlling means and an operating mechanism therefor;

FIG. 6 is an isometric view illustrating a different form of operating mechanism for the flow-controlling means of FIG. 5; and

FIG. 7 is a diagrammatic view showing a development of the cam employed in the device of FIG. 6.

The turbine shown in FIGS. 1 and 2 comprises a rotor 10 having radial blades 11 and mounted for rotation within an enclosing housing 12. The housing 12 has a radially projecting inlet portion 13 having outwardly converging side walls 14 and terminating in an inlet opening 15 adapted to receive flowing gases from any appropriate source (not shown). The base of the inlet portion 13 has a substantial extent circumferentially of the housing 12, and within it is mounted means for regulating the gas flow to control operation of the turbine.

The flow-regulating means shown in FIGS. 1 and 2 comprises a V-shaped controller having a pair of similar wings 20 and 21 disposed at an obtuse angle. The wings 20 and 21 are rigid with each other and with a stem 22 which is located at the junction of the wings and projects perpendicularly to the common plane of the wings. The stem 22 is rotatably mounted in the housing-portion 13, and one end of it extends outwardly through and beyond a wall of the portion 13 to be accessible for adjustment of the controller about the axis of the stem.

Shrouds 24 and 25 are respectively associated with the wings 20 and 21. Each of such shrouds is conveniently formed of sheet metal bent into a U-shape in cross-section to provide side walls and an intermediate wall. Each shroud is disposed with its intermediate wall adjacent a side wall 14 of the housing portion 13 and with its side walls, which are generally triangular in shape, extending inwardly on opposite sides of the associated controller wing 20 or 21. At their adjacent ends, the corresponding side walls of the two shrouds overlap, and both pairs of side walls are provided with openings

which receive the stem 22. The shrouds are freely movable about the axis of the stem 22 and are respectively urged toward the turbine-axis, as by springs 26 and 27, and toward engagement with stop pins 28 and 29 so located as to prevent either shroud or its associated controller-wing 20 or 21 from coming into contact with the rotor 10.

In FIGS. 1 and 2, the controller is disposed to provide for full-throttle operation of the turbine in the clockwise direction. The stem 22 has been rotated to its clockwise limit to bring the wing 20 into engagement with the pin 28, and the spring 26 has forced the shroud 24 also into engagement with such pin. The other controller wing 21 has engaged the intermediate wall of the shroud 25 and has forced such shroud away from its stop-pin 29. In this condition, the wing 20 and shroud 24 define a nozzle-like duct open at its upper end to receive gas entering through opening 15. Such duct is also open at its lower or discharge end, as the shroud is so constructed that when both it and the wing 20 are in engagement with the pin 28, the end of the wing 20 will be spaced from the intermediate wall of the shroud. At the opposite side of the deflector, the corresponding nozzle-like duct is closed, as the spring 27 holds the intermediate wall of the shroud 25 in contact with the end of the wing 21. In consequence, all the gas entering the opening 15 will be discharged tangentially in a clockwise direction against the rotor-blades 11.

For part-throttle operation in a clockwise direction, the stem 22 and controller 20—21 are rotated in a counter-clockwise direction, thus moving the end of the wing 20 toward the intermediate wall of the shroud 24, which remains stationary against the pin 28 under the influence of spring 26. At the same time, the spring 27 acts on the shroud 25 to maintain engagement of its intermediate wall with the end of the wing 21 and prevent discharge of gas in a counter-clockwise direction from the shroud 25. Continued counter-clockwise rotation of the controller results in eventual complete closing of the passage through the shroud 24 and, after the shroud 25 engages the pin 29, progressive opening of the passage through the shroud 25.

Depending on whether or not it is deemed undesirable to load the gas-source by full throttling of its output, the mechanism of FIGS. 1 and 2 can be constructed in either of two different forms. If it is not deemed necessary to avoid full throttling, the shroud walls can be so shaped and the stop pins 28 and 29 so located that either controller wing, in moving away from fully open position, will attain closed position against the intermediate wall of its associated shroud before the other shroud engages its stop pin. Since engagement of either shroud with its stop pin is necessary to opening of the passage through the shroud, both passages would be closed, and the gas-source fully throttled, when the controller was in mid-position. Alternatively, the stop pins 28 and 29 can be so located as to engage a shroud before the passage through the other shroud has been fully closed. In such an arrangement, the passages through both shrouds would be partially open when the controller was in or adjacent its mid-position and gas would be discharged in both directions against the turbine blades, thus making it possible to reduce the application of the net driving effort, even to zero, without completely throttling the gas-source.

Preferably, the walls 14 of the housing-portion 13 are offset outwardly above the tips of the wings 20, 21 and shrouds 24, 25, leaving shoulders 31 closely adjacent the paths of movement of such wing and shroud tips. Such offsetting provides a space for the reception of each wing-tip and shroud when the latter moves away from engagement with its associated stop pin 28 or 29. This

arrangement makes it possible for the intermediate wall of a shroud in engagement with its stop pin to lie substantially flush with that part of the housing wall below the shoulder, thus providing for the entering gas a substantially continuous flow-guiding surface free from obstruction which would impede gas-flow.

It is possible to eliminate the shrouds **24** and **25** and to control the direction and rate of flow of the entering gas by cooperating of the tips of the wings **20**, **21** with the shoulders **31**. However, in such an arrangement, when either wing-tip moved inwardly beyond its associated shoulder **31** to open a passage for flow of gas to the rotor, the shoulder would provide a partial obstruction to gas-flow and cause a loss of energy.

The embodiment of the invention illustrated in FIGS. 3 and 4 provides an improved streamlining of the inlet passage, especially at full-throttle. In it, the inlet portion of the housing comprises opposed, front and rear walls **35** and **36** and side walls **37** and **38** which diverge toward the turbine-housing **12**. The side walls **37** and **38** are of elastic stock, and have a width substantially equal to the spacing of the front and rear walls so that they can enter therebetween. Extending between the front and rear walls **35** and **36** is a V-shaped flow director having wings **39** and **40** which diverge toward the housing **12**, or in the direction of gas flow. Adjacent the ends of the wings **39** and **40**, shafts **41** and **42** are supported from the front and rear walls **35** and **36**, such shafts projecting through the front or rear walls for connection to any suitable control mechanism. Vanes **43** and **44** located between the front and rear walls are secured to the shaft **41** and **42** respectively to be rotated by the shafts in controlling the direction and rate of flow of gas entering the housing **12**.

Each of the side walls **37** and **38** is secured at its lower end to the housing **12** and extends upwardly therefrom well beyond the flow-director **39—40** into overlapping relation with rigid side-wall portions **45** and **46**. Springs **47** connected to the upper ends of the side walls urge them upwardly and hold them against the outer faces of the rigid wall portions **45** and **46**. By this arrangement, either side wall can be deflected inwardly against the flow-director to cooperate with the opposite wing thereof in forming a smoothly curved, essentially continuous surface confining gas flowing to the housing along the other side wall. The side wall **38** is shown so deflected in dotted lines in FIG. 4.

Means for deflecting the side walls inwardly may take any appropriate form. That shown in the drawings comprises a pair of shafts **51** and **52** which lie outwardly of the side walls and are rotatably mounted in ears **53** provided on the front and rear walls **35** and **36**. Such shafts carry arms **54** and **55** on the outer ends of which are mounted rollers **56** each adapted to engage the adjacent side wall and deflect it toward, and even into, engagement with the director **39—40** as the arm swings inwardly.

Any appropriate means may be provided for controlling the position of the vanes **43**, **44** and the arms **54**, **55**, either jointly or independently. The precise form of such means will depend to an extent on whether or not it is desired to be able to position both vanes simultaneously in open position (as shown in full lines in FIG. 4) for the purpose of "unloading" the source of gas supplied to the turbine. The form of controlling means shown in FIG. 4, which is not capable of positioning both vanes simultaneously in full open position, comprises a rotatable cam plate **60** having cam grooves or slots which receive pins **61** mounted on the ends of arms **63** and **64** secured respectively to the vane-supporting shafts **41** and **42**. The pin-receiving slots of the cam plate **60** respectively include spiral portions **65** and **66** and concentric portions or lands **67** and **68**. Each concentric slot-portion joins its associated spiral portion at the inner end thereof and lies diametrically opposite the spiral portion of the other slot.

A pin **70** mounted in an eccentric position on the cam plate **60** is connected to the inner ends of two links **71** and **72** the outer ends of which are connected to arms **73** and **74** secured respectively to the shafts **51** and **52**.

In the condition illustrated in FIG. 4, the cam plate **60** is set for full-throttle operating of the turbine in the clockwise direction. The pin **61** on the arm **63** lies at the outer end of the spiral slot-portion **65** to hold the vane **43** in fully-open position, while the pin **61** on arm **64** lies at the end of the concentric slot portion **68** to maintain the vane **44** in closed position. The pin **70**, at the limit of its motion in a clockwise direction, holds the arm **54** in inoperative position and the arm **55** in such position that the side wall **38** is deflected inwardly against the wing **40** of the flow-director. In this condition, a smooth-walled, streamlined passage is provided for the entering gas, which discharges past the open vane **43** to impinge upon the blades **11** and drive the rotor **10** in the clockwise direction.

On movement of the cam plate in a counterclockwise direction from the position of FIG. 4, the spiral slot-portion **65** will initially cause the vane **43** to move toward closed position, which will be attained when the inner end of the slot-portion reaches the pin. During such initial movement of the cam plate, the pin **61** on arm **64** will occupy the concentric slot-portion **68**, and the vane **44** will therefore remain closed. As counterclockwise movement of the cam plate continues, the concentric slot-portion **67** will move into association with the pin **61** on arm **63**, and the spiral slot-portion **66** will cause the vane **44** to move toward open position. Thus the vanes **43** and **44** may be jointly adjusted to provide for full-throttle or part-throttle operation of the turbine in either direction.

During movement of the cam plate **60** in the counterclockwise direction as above described, the pin **70**, acting through the links **71**, **72** and arms **73**, **74** will swing the arm **54** inwardly to force the side wall **37** against the wing **39** and the arm **55** outwardly to permit the side wall **38** to assume its normal position.

The structure shown in FIG. 5 embodies the vanes **43** and **44** and vane-controlling mechanism of FIG. 4, but employs a different arrangement for streamlining the gas flow. In that arrangement, the side walls of the inlet portion of the housing comprise rigid portions **81** and **82**, which converge upwardly to a point adjacent the apex of the flow-director **39—40**, and movable sections **83** and **84**, each pivotally mounted at its upper end and swingable between a first position in which it lies flush with its associated rigid portion **81** or **82** and a second position in which it lies flush with the opposite wing **40** or **39** of the flow-director. In FIG. 5, section **83** is shown in its first position and section **84** in its second position.

Control of the swinging sections **83**, **84** is effected through a member **85** pivotally mounted between the pivots **83'**, **84'** about which the sections **83** and **84** respectively swing. The member **85** has a pair of oppositely projecting arms operatively connected to arms **86** and **87** respectively rigid with the sections **81**, **82** and projecting outwardly from the pivots **83'**, **84'**. As will be clear from FIG. 5, the arrangement is such that by rocking the member **85**, one of the sections **83** and **84** can be moved from its first position to its second position while the other section is moved from its second position to its first position. For the purpose of so rocking the member **85** it includes a third arm which extends downwardly into a position overlying the cam plate **60**, where it is provided with a slot having two symmetrical portions **88** and **89** which receive a pin **90** eccentrically mounted on such cam plate. Each of the slot-portions **88** and **89** is in the form of a circular arc, but the two arcs have different centers which are so spaced that when the member **85** is at one limit of its swinging movement one slot-portion will be concentric with the cam plate **60** while the other

will be concentric with the cam plate when the member **85** is at the opposite limit of its swinging movement.

In the condition shown in FIG. 5, the cam plate **60** occupies the same position as in FIG. 4, the vane **43** is in full-open position, and the vane **44** in fully closed position. The member **85** is in the counterclockwise limit of its swinging movement, to hold the section **83** in its first position and the section **84** in its second position, and the slot-portion **88**, which is occupied by the pin **90**, is concentric with the plate **60**. Because of the latter condition, the cam plate **60** can be rotated counterclockwise to move the vane **43** toward closed position while the member **85** and the sections **83** and **84** remain stationary until the pin **90** enters the other slot-portion **89**. As such slot portion **89** is not concentric with the cam plate, continued movement of the cam plate will rock the member **85** in a clockwise direction causing it to move section **84** to its first position and section **83** to its second position. Thus a smooth-walled passage for the entering gas is provided irrespective of which vane **43** or **44** is open and irrespective of whether it is fully or only partly open.

To expedite reversal in the positions of the sections **83**, **84** when the cam plate **60** passes through the mid-point of its movement, the outer ends of the arms **86** and **87** may be interconnected by a helical tension spring **91**, the effective axis of which will pass through the plane of the pivots **83'** and **84'** when the member **85** passes through the mid-point of its movement.

FIGS. 6 and 7 illustrate an alternative form of means for controlling the positions of the vanes **43**, **44** and wall-sections **83**, **84**. Here, the cam plate **60** is replaced by a cylinder cam **95** having three axially spaced, helical cam-grooves **96**, **97**, and **98**. The two end grooves **96** and **98** receive cam followers **96'** and **98'** carried respectively by the vane-controlling arms **64** and **63**, while the middle groove **97** receives a cam follower **97'** on the third arm of the member **85**.

A preferred form for the cam grooves **96**, **97**, and **98** is shown in FIG. 7, wherein the cam **95** is shown in development. As there shown, the grooves **96** and **98** at their mid-points have relatively short plane portions or dwells **96***a* and **98***a* so disposed axially that when occupied by the followers **96'** and **98'** both vanes **43** and **44** will be partially open. With the vanes in such positions gas entering the housing **12** will be substantially throttled and, since it discharges in both directions against the rotor, no substantial torque will be developed by the turbine. Movement of the cam **95** in one direction (downwardly in FIG. 7) from its mid-position will successively bring three additional portions **96***b*, **96***c*, and **96***d* of the groove **96** into association with the follower **96'** and two portions **98***e* and **98***f* of the groove **98** into successive association with the follower **98'**. Movement of the cam in the opposite direction from its mid-position will bring two portions **96***e* and **96***f* of the groove **96** successively into association with the follower **96'** and three portions **98***b*, **98***c*, and **98***d* of the groove **98** into successive association with follower **98'**. Groove-portions **96***b* and **98***b* are rises having a sufficient axial extent to effect complete closing of the respectively associated vanes **44** and **43**. Groove-portions **96***c* and **98***c* are dwells each of which, when occupied by its follower, holds the associated vane in fully closed position. Each of groove-portions **96***d* and **98***d* is inclined to effect progressive opening of the vane associated with the follower entering it. Groove portions **96***e* and **98***e*, which are respectively coextensive circumferentially with dwells **98***c* and **96***c*, are rises each of sufficient axial extent to effect full opening movement of the associated vane. Groove portions **96***f* and **98***f* are dwells respectively coextensive circumferentially with rises **98***d* and **96***d*, each serving when occupied by its follower to hold the associated vane in open position.

When the cam **95** is in the mid-position shown in the drawings, the cam follower **97'** on the member **85** occupies the mid-point of a rise **97***a* of the groove **97**, and the wall-sections **83** and **84** lie intermediate their respective first and second positions. The rise **97***a* desirably has a relatively steep pitch so as to bring one wall section quickly into its first position and the other quickly into its second position when the cam **95** is displaced from mid-position. The hand of the rise **97***a* is of course such as to bring the wall section **83** into its first position and the section **84** into its second position when the cam **95** is rotated to open the vane **43** and close the vane **44**. At its one end, the rise **97***a* joins a dwell **97***b* which extends circumferentially to the end of groove portion **96***c* and its other end joins a dwell **97***c* extending circumferentially to the end of groove portion **98***c*. At the ends of its dwells **97***b* and **97***c*, the groove **97** is shown as provided with rises **97***d* and **97***e*, the purpose of which will become apparent below.

As will be clear, movement of the cam **95** from its central position in one direction—downwardly in FIG. 7—will close vane **44** and open vane **43**, and at the same time, the member **85** will be rocked to bring the section **83** into its first position and the section **84** into its second position. The movement of the vane **44** and of the wall sections to their respective ultimate positions will occur relatively quickly and will be completed before the vane **43** is fully opened. Continued movement of the cam in the assumed direction will progressively open the vane **43** until the condition shown in FIG. 5 is attained, the cam followers **96'** and **97'** meanwhile respectively occupying the dwells **96***c* and **97***b*. For counterclockwise rotation of the turbine, the cam **95** is moved in the opposite direction (upward in FIG. 7).

The groove-portions **96***d*, **97***d*, **98***f*, **96***f* and **98***d* are particularly useful where the cam **95** is controlled by a speed limiting governor and the gas source is of such a character that abrupt throttling of its output would be undesirable. Consider, for example, the situation existing if the turbine, operating under full throttle, was suddenly relieved of load. The resultant tendency of the turbine to over-speed could be corrected by moving the cam to, or even through, its mid-position; but if such cam movement was effected abruptly, the consequent abrupt throttling of the inlet passage might tend to overload or produce erratic operation of the gas-source. The cam portions last referred to make it possible to reduce the speed of the turbine quickly without unduly loading the gas-source. For example, if with the cam-follower **96'** occupying the groove-portion **96***c*, the follower **98'** at or near the upper end of the groove-portion **98***e*, and the turbine rotating clockwise, an abrupt speed reduction is desired, the cam may be moved to bring the followers **96'** and **98'** into the groove-portions **96***d* and **98***f*, respectively, and the cam-follower **97'** into the rise **97***d*. Such operation will leave open the already fully-opened vane **43** to continue the clockwise introduction of the gas, but will open the previously closed vane **44** and section **84**, thereby causing gas to be also introduced in a counterclockwise direction. The latter gas, by opposing rotation of the rotor, will reduce the speed while, at the same time, avoiding the imposition of undue load on the gas-source.

The cam **95** may be provided with additional cam surfaces for controlling auxiliary equipment, such as the gas-source.

While I have described the various illustrated embodiments of my invention as providing alternatively for rotation of the turbine in either direction, it will be understood that the invention can be used in turbines which, in normal operation, rotate in but one direction. In such cases, the possibility of reversing the tangential direction of the gas impinging on the rotor may be utilized to provide braking. Depending upon the type of vane-control mechanism employed, the net torque applied to the rotor can, without throttling the gas flow, be varied from zero to a maximum in either direction by

simply varying the division of the flowing gas between the two nozzle-like passages which the vanes in part define.

Because the illustrated embodiments provide for complete reversibility of the turbine and for similar operation in opposite directions, the gas controlling elements are symmetrically arranged and the rotor blades 11 are radial. If the operational characteristics are not to be the same for opposite directions of rotation, such symmetry will not be necessary and may even be undesirable.

It will be further understood that the specific embodiments of the invention illustrated and described above are set forth merely by way of examples, that other embodiments are possible, and that the scope of the invention is to be measured by the appended claims.

I claim as my invention:

1. A reversible turbine, comprising a housing, a rotor having generally radial blades rotatably mounted within said housing, an inlet conduit having opposite side walls flaring toward said housing and joining it substantially tangentially, means including vanes pivotally mounted between said flaring walls for controlling the flow of gas toward said rotor, each of said vanes extending in the general direction of gas flow from its axis of pivotal mounting to a point adjacent the periphery of said rotor and in part defining a nozzle-like passage progressively decreasing in area toward an outlet opening at the tip of the vane, each of said vanes being swingable about said axis to vary the size of said outlet opening, and control means for adjusting the position of each vane about its axis, the pivotal axis of each vane being located sufficiently far from the associated wall of the inlet conduit that the vane and wall, in all positions of vane adjustment, will always converge relatively to each other in the direction of gas flow.

2. A turbine as set forth in claim 1 with the addition that said control means includes a single control member openable to effect joint adjustment of said vanes.

3. A turbine as set forth in claim 1 with the addition of a movable member cooperating with each vane in defining the nozzle-like passage.

4. A turbine as set forth in claim 1 with the addition that said vanes are rigid with each other and are swingable about a common axis.

5. A turbine as set forth in claim 1 with the addition of a shroud associated with each vane, each shroud being pivotally mounted on the axis of its associated vane and being of U-shaped cross-section to provide a pair of opposed, spaced walls between which the vane swings and an intermediate wall toward and away from which the vane swings, means urging each shroud to swing about its axis in such a direction as to cause its intermediate wall to approach the vane, and stationary stop means for limiting swinging of each shroud under the influence of said urging means.

6. A turbine as set forth in claim 1 with the addition that said vanes are pivotally mounted on spaced axes, a flow-divider having wings which extend in converging relationship from the pivoted ends of said vanes anteriorly with respect to the direction of gas flow, and adjustable means for controlling the division of flowing gas between opposite sides of said flow-divider.

7. A turbine as set forth in claim 6 with the addition of common means for adjusting said vanes and said division-controlling means.

8. A turbine as set forth in claim 6 with the addition that said division-controlling means includes a pair of members extending anteriorly of said inlet conduit from said flow-divider, the anterior ends of said members being located respectively adjacent the side walls of the inlet conduit, each of said members being movable between a first position in which it is spaced transversely of the inlet conduit from said flow divider and a second position in which it extends obliquely with its posterior portion lying in close proximity to said flow-divider.

9. A reversible turbine, comprising a housing, a rotor having generally radial blades rotatably mounted within said housing, an inlet conduit having opposite side walls flaring toward said housing and joining it substantially tangentially, a flow-divider located centrally in said inlet conduit for directing flow toward said side walls, means located anteriorly of said flow-divider and adjustable to control the division of flowing gas between opposite sides thereof, said means being capable of adjustment to direct substantially all the flowing gas alternatively to either side of the flow-divider, vanes pivotally mounted on transversely spaced parallel axes adjacent the posterior end of said flow-divider, each of said vanes extending generally in the direction of gas flow from its pivotal axis and being swingable thereabout to cooperate with the adjacent side wall of the inlet conduit in defining a nozzle-like passage of progressively decreasing area in the direction of gas flow, and common means for adjusting said vanes and said division-controlling means.

10. A turbine as set forth in claim 9 with the addition that said common means comprises an adjustable cam and cam-followers respectively connected to said vanes and division-controlling means, said cam being so constructed and arranged as to permit the cam to be moved to adjust the vanes while the adjustment of the division-controlling means remains unchanged.

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