# United States Patent [19]

**Stalker**

[11] **3,837,760**

[45] **Sept. 24, 1974**


[54] **TURBINE ENGINE**


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[52] **U.S. Cl.** ..... **415/181,** 60/39.65, 415/207, 415/209

[51] **Int. Cl.** ..... **F04d 21/00,** F04d 29/44

[58] **Field of Search** ..... 138/37; 415/207, 181, 209, 415/219 R; 60/39.66, 39.65, 39.69



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*Attorney, Agent, or Firm*—Biebel, French & Bugg



[57] **ABSTRACT**

A turbine type engine employs an axial type compressor in which the rotor has flow passages between the blades of decreasing cross-sectional area from inlet to outlet while the blades are configured to turn the flow of fluid substantially back toward its original direction, so that the supersonic flow is discharged at a relatively flat angle to the plane of rotation of 30° or less. The direction of discharge flow of the compressor has its greatest component of velocity substantially in the peripheral direction. A collector is used free of stator vanes leading to a tubular type diffuser. The diffuser is formed with tubular segments positioned in successive downstream relation defining peripheral flow slots. The discharge of the combustor is directed to a radial inflow turbine.


**2 Claims, 8 Drawing Figures**

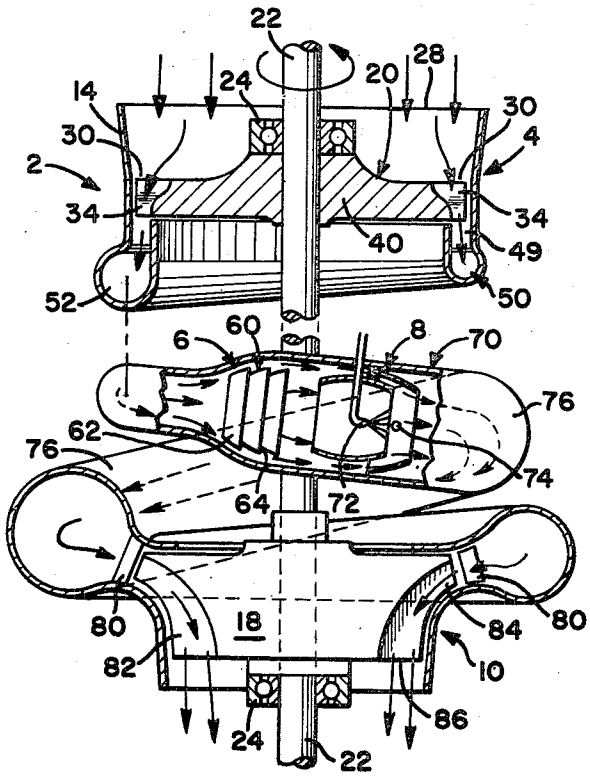


FIG-1

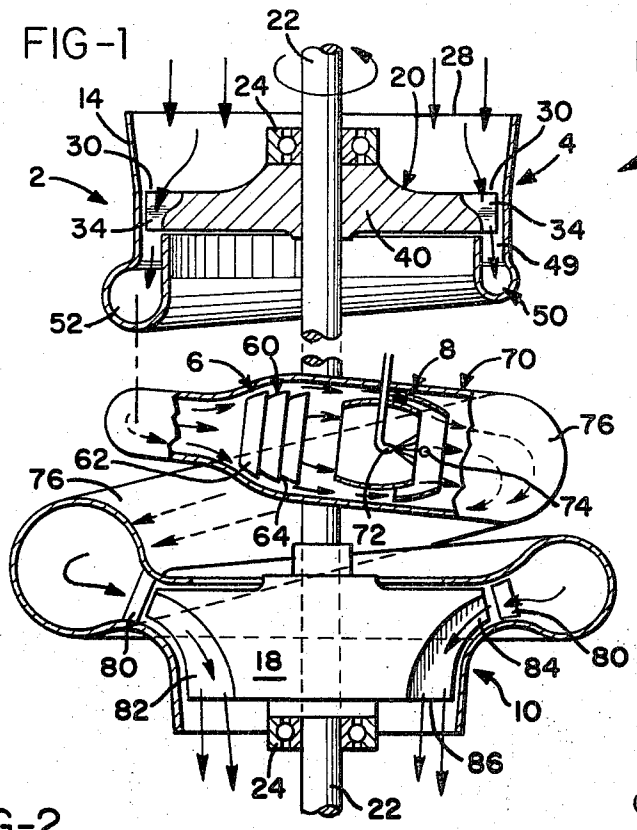



FIG-4

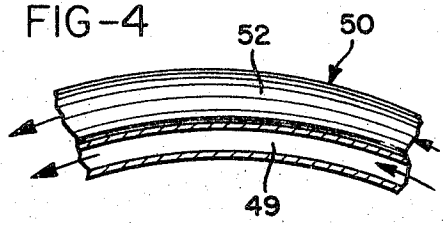



FIG-8

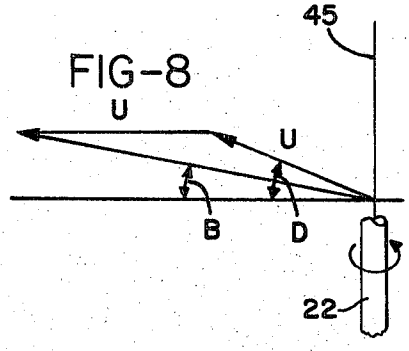



FIG-5

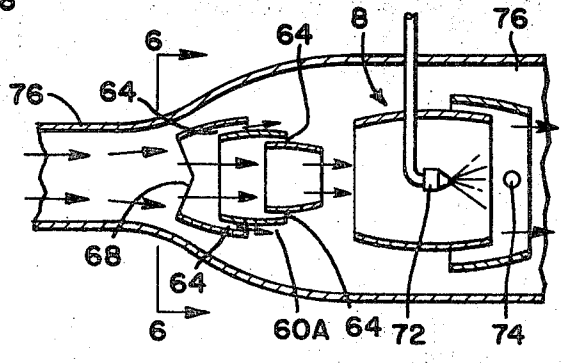



FIG-2

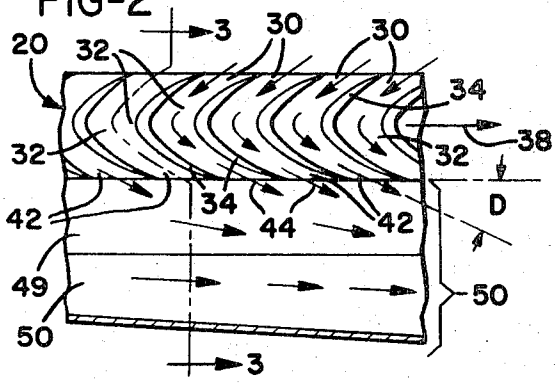



FIG-6

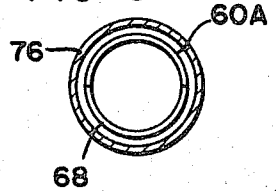



FIG-3

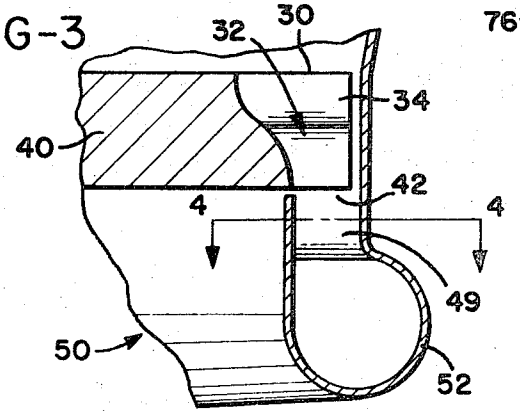
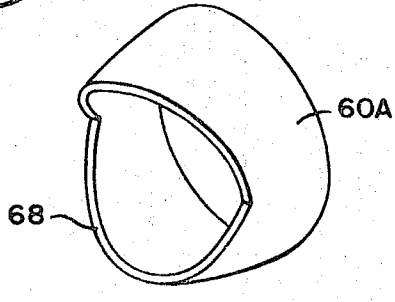



FIG-7



# TURBINE ENGINE

## BACKGROUND OF THE INVENTION

This invention relates to rotary fluid machines where energy is exchanged between a fluid and a rotor and more particularly to the combination of an axial flow rotor which turns the flow to discharge into an axial collection chamber.

From a cost and weight point of view, it is desirable to obtain as large as possible of a pressure rise in each stage of an axial flow compressor. For a selected rate of rotation, this may be done by turning the flow of fluid through the rotor back on itself; that is, the flow is admitted to the rotor passages at a relatively small angle to the plane of rotation and is discharged from the passage in the direction of rotation at a small angle to the plane of rotation. It is difficult to turn this peripheral flow leaving the rotor into the axial direction efficiently to achieve a static pressure rise.

Supersonic rotors are known for producing high total head ratios, but it has been very difficult to convert the high velocity flow leaving the rotor into static pressure. The references made here to supersonic rotors are those discharging a fluid flow over whose major cost section the velocity is supersonic relative to the adjacent walls. The efficiency of this conversion has, in fact, been too low to provide an engine competitive with those using subsonic rotors.

My U.S. Pat. No. 2,953,295 of 1960 deals with this problem. However, in that patent, the discharge is not at a flat angle to the rotor. That patent does not show the present combination with a diffuser or the annular duct to reduce the supersonic flow by causing a series of small shock waves. The patent of Owner, et al., U.S. Pat. No. 2,567,079 of 1951, shows external combustion chambers but does not show an axial flow rotor. Rather, it shows a centrifugal compressor with the compressed flow delivered radially from the rotor into ducts.

## SUMMARY OF THE INVENTION

In the present invention, the flow is continued in an axial compressor in the generally peripheral direction, and an efficient and low-cost means of diffusion is used to provide a high static pressure. The rotor itself is provided with accelerating passages, along their forward portions and at least downstream beyond their locality of maximum curvature. This is done by progressively reducing the cross-sectional areas of each of the compressor passages. Since the passages between the blades are reduced in cross-sectional flow area, the flow will be turned by the blades while the flow is being accelerated. Hence, the passages are each reduced in cross-sectional area downstream beyond the locality of change in direction. The rotor is then preferably turned at such a speed that the flow enters each rotor passage of the compressor at a speed less than the velocity of sound relative to the rotor and emerges at supersonic speeds relative to the adjacent portions of the casing. By this means, a high static pressure may be achieved. Still higher pressure ratios may be achieved by increasing the peripheral speed of the rotor to sonic or supersonic speed at the inlets of the rotor flow passages. In particular, the rotor discharges its fluid flow at substantially high supersonic speeds relative to the walls immediately adjacent the aft or discharge side of the rotor.



The invention accordingly resides in part in the combination of the axial flow rotor which turns the flow to discharge it at a relatively flat angle with respect to the plane of rotation, preferably 30° or less, so that the direction of the discharged flow has its greatest component of velocity substantially in the peripheral direction. If an attempt is now made to turn the discharged flow into the axial direction and diffuse it to an increased static pressure, this meets with a very low efficiency.

According to the present invention, no attempt is made to turn the flow immediately to the axial direction, but advantage of the flat angle is taken to direct the flow in the peripheral direction, i.e., in the direction about the axis of rotation or substantially in the plane of rotation.

In flowing along the curved surface of the collector, small shock waves occur at successive increments of this surface and continuously reduce the supersonic velocity. Also, the duct downstream from the collector is curved to create small surface shockwaves along its interior surface. The flow is directed in the peripheral direction through a tubular-type diffuser. The diffuser discharges the flow preferably into an annular chamber providing an exit into the turbine rotor. Preferably, the entrance edges of the diffuser are slanted relative to the local flow to minimize shock losses for the diffuser. The velocity components normal to these edges can be of low supersonic velocity or less than sonic velocity.

An object of the invention is to provide a rotary compressor having a rotor generating a supersonic flow velocity and an efficient means of diffusing the fluid flow.

Another object of the invention is the provision of an axial compressor in which the exits of the rotor flow passages face peripherally and move in the peripheral direction rather than in the axial direction.

A further important object of the invention resides in the combination of an axial-flow rotor which turns the flow to discharge it at a relatively flat angle with respect to the plane of rotation, preferably 30° or less, so that the direction of the discharged flow has its greatest component of velocity substantially in the peripheral direction.

A still further object of the invention is to provide a compressor in which a rotor has flow passages of decreasing cross-sectional area from inlet to near the exit, to accelerate the fluid flow therethrough, in combination with an efficient diffuser.

These and other objects and advantages of the present invention will become apparent from the following description, the accompanying drawings and the appended claims.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a somewhat diagrammatic axial section through an engine having a compressor and diffuser section constructed according to this invention;

FIG. 2 is an enlarged, developed fragmentary section through the compressor rotor and case showing a development of the hub and blades of the rotor;

FIG. 3 is an enlarged fragmentary transverse section taken generally along the line 3—3 of FIG. 2;

FIG. 4 is a fragmentary radial section through a portion of the collector;

FIG. 5 shows a modified or alternate form of diffuser which may be used with the invention;

FIG. 6 is an elevational view of the diffuser taken along the line 6—6 of FIG. 5;

FIG. 7 is a perspective view of the inlet end of one of the diffusers of FIG. 5 showing the slanted leading edges; and

FIG. 8 is a vector diagram useful in understanding the operation of the compressor.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, the engine is indicated generally by **2.** It is comprised of the compressor **4,** the diffuser **6,** the combustor **8** and the turbine **10.**

The compressor is comprised of the case **14** and the compressor rotor **20** mounted on the shaft **22** rotatable in the bearings **24.** The inlet **28** of the compressor admits air to the inlets **30** of the compressor rotor passages **32** between the blades **34** thereof.

It is to be noted that the inlets of the compressor rotor passages face in the general direction of rotation **38.** The exits **42** of these passages also face in the general direction of rotation. The direction **44** of discharge of the rotor air makes a flat or very small angle B in the order of 30° or less, with the plane of rotation of the rotor, i.e., a plane normal to the axis of rotation.

As shown particularly in FIGS. **1** and **2,** the compressor rotor comprises a hub **40** on which are fixed the plurality of the compressor V-shaped vanes or blades **34** extending radially and spaced peripherally thereabout to define the rotor passages **32.** These passages admit air (or other gas) into the inlets **30** and discharge it through the exits **42.** The vanes **34** are highly curved to discharge substantially along the peripheral direction of rotation, preferably more along the peripheral than the axial direction.

The hub **40** increases in diameter rearward, i.e., downstream, as shown in FIG. **3,** so that the cross-sectional areas of each rotor passage contracts from a maximum substantially at the inlet **30** to a minimum near the exit **42** to give the flow an acceleration up to and beyond the curved central portion of each vane **34.** In consequence, the flows discharged from the rotor passage exits have a higher velocity at the exits than at the inlets relative thereto. The acceleration of the flow enables it to be turned through great angles by the vanes **34.** For instance, the flow may enter an inlet at an angle to the plane of rotation of the order of 20° and discharge from the exit at a like angle in the direction of rotation. This would represent a turning of 140°.

With reference to FIG. **8,** if the rotor passages discharge at discharge angle D of 45° past the axis of rotation **45** with a flow velocity vector, relative to the plane of rotation of the rotor, of U, and the peripheral velocity of the rotor is U, then the direction of the flow relative to the side walls of the collector will be at an angle B of about 23°, or in other words, about one-half the angle of 45°. This flow is substantially along the wall direction and is directed therealong very efficiently. By discharging the supersonic flow into a tubular means or conductor curved along the direction of flow with a relatively small radius of curvature comparable to the rotor tip radius, inclined small shock waves are induced which reduce the flow velocity.

The air leaving the rotor proceeds in the peripheral or outward direction within the collector **50** which is considered as a part of the compressor. It comprises the nozzle portion **49** and the scroll portion **52.** The nozzle portion preferably has an open annular area free of vanes. The scroll portion preferably presents an open or substantially unobstructed annular area which increases in axial width and cross-sectional area along the flow direction to receive the increasing quantity of flow as the rotor proceeds around the axis of rotation.

The flow from the collector **50** enters the parallel or tubular stator or diffuser **60** which is characterized by having walls enclosing the flow and disposed substantially along the flow direction.

The diffuser has a relatively wide included angle of diffusion in the order of 40° as shown in FIG. **1.** It comprises the rings **62** spaced apart axially to provide the slots **64** therebetween. The flows through these slots provide boundary layer control and thereby facilitate a high efficiency of diffusion in a short length.

In a flow passage of an axial flow rotor, the gas flow takes on components of velocity in planes of rotation. That is, there is a local flow from a surface of a blade toward the surface of the adjacent blade. This effect occurs mainly adjacent the ends of the vanes and is especially detrimental when the rotor adds a relatively large amount of energy to the flow. This component makes the angle of approach of the flows from the rotor passages to radial stator vanes improper at the localities adjacent the ends of the stator vanes, and thereby engenders large losses of energy or pressure recovery.

In the subject invention employing rings or vanes **60,** the peripheral component does not act transversely to these vanes, but in large part, acts parallel to their leading edges along their surfaces. There are, therefore, no large losses induced by improper angular approaches which would cause turbulence because of flow separation from the surfaces.

As shown in FIGS. **5–7,** leading edges **68** of the tubular stator **60A** may be slanted to accept the supersonic flow relative thereto with no or minimized shock.

The air flow next enters the combustion chamber **70** wherein is positioned a fuel nozzle **72** and an ignitor **74.** From here the products of combustion and the admixed air enters the combustion gas collector **76.** It then flows through the turbine stator **80** into the turbine radial inflow rotor passing into the turbine passages **82** at their inlet **84** and discharging from their exits **86.**

This combination of a compressor rotor adapted to accelerate the flow to supersonic speeds with a chiefly peripheral discharge and the tubular diffuser to receive the supersonic flow provides for efficient diffusion of the supersonic flow to large static pressures.

While the forms of apparatus herein described constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to these precise forms and that changes may be made therein without departing from the scope of the invention.

What is claimed is:

**1.** An axial flow compressor comprising a rotor with smoothly curved V-shaped blades and blade exit portions directed so that the tangent to the mean camber line adjacent the exit is directed past the axis of rotation in the direction of rotation by at least 45° to provide a discharge at an angle less than 30° to the plane of rotation of said rotor, said rotor having hub diameters increasing in diameter from adjacent the leading edges to a locality substantially downstream from the

maximum curvature of the blades to provide contracting cross-sectional areas of the flow passages between peripherally adjacent blades to accelerate the flow therethrough at the same time it is being turned to discharge the flow with a substantial peripheral component, and a collector scroll free of vanes adjacent the exit side of said rotor to receive said peripheral flow, said collector having an axial nozzle portion leading directly into a scroll portion providing an open and substantially unobstructed annular area which increases in axial width and cross-sectional area along the flow direction, said collector defining a peripherally curved inside surface along the direction of flow.

2. In combination, a case, an axial flow rotor mounted in said case for rotation about an axis, said rotor having smoothly curved blades and blade exit portions directed so that the tangent to the mean camber line adjacent the exit is directed past the axis of rotation in the direction of rotation by at least 45°, the improvement comprising the fact that the rotor has hub diameters increasing in diameter from adjacent the leading edges to a region substantially downstream from the maximum curvature of the blades to provide flow passages between adjacent blades having contracting cross-sectional areas to accelerate the flow therethrough, a substantially vaneless collector adjacent the exit side of said rotor to receive said flow and direct said flow transversely to said axis into a duct extending transversely to said axis, means to rotate said axial flow rotor to provide an exit flow therefrom, at supersonic velocity relative to said case, and a combustion chamber in said duct to heat said flow.

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