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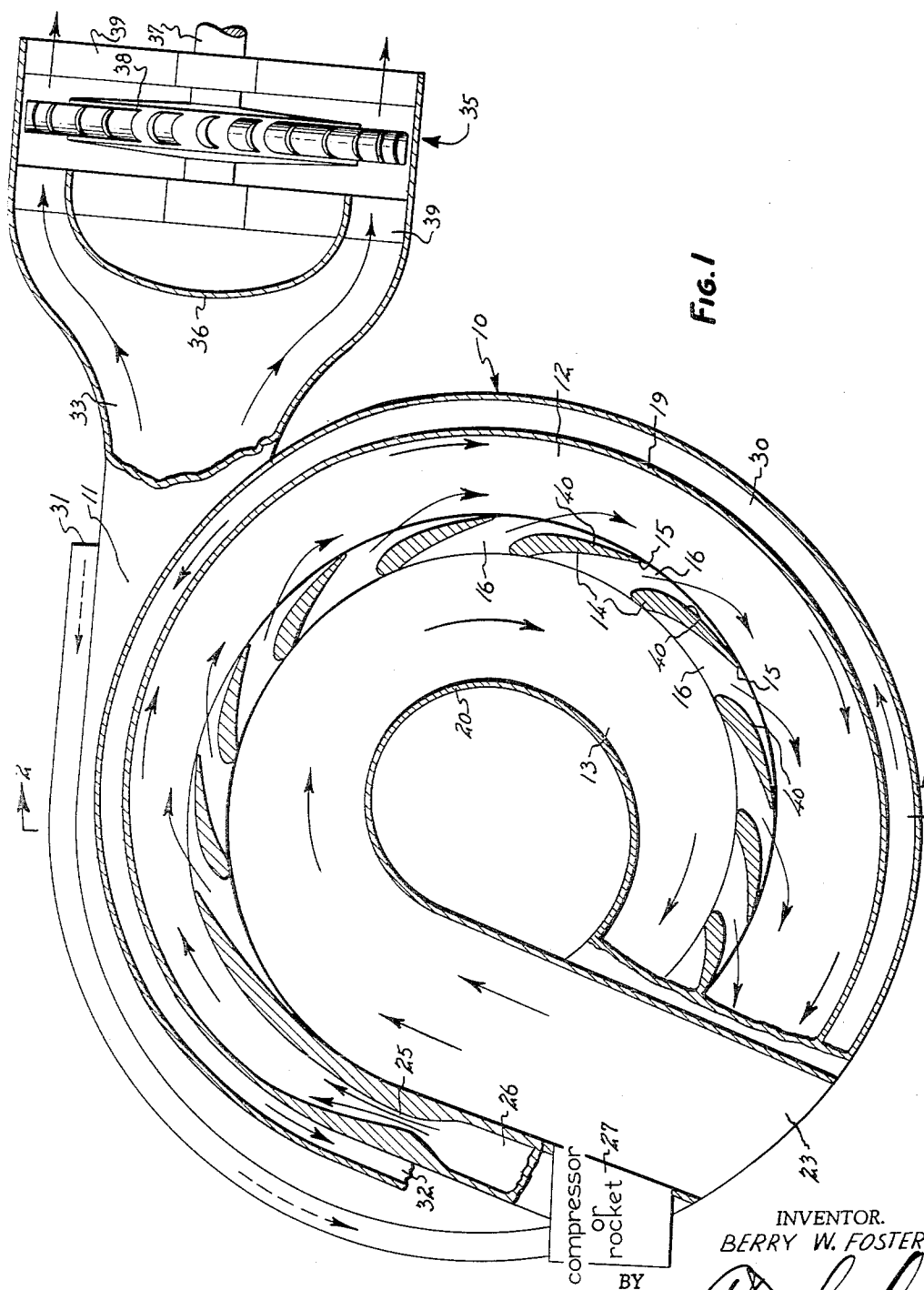
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Filed March 21, 1958

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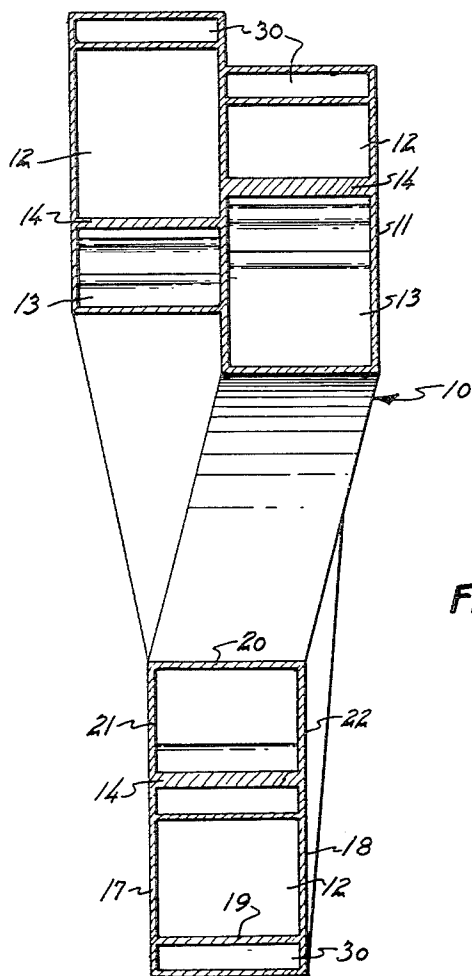
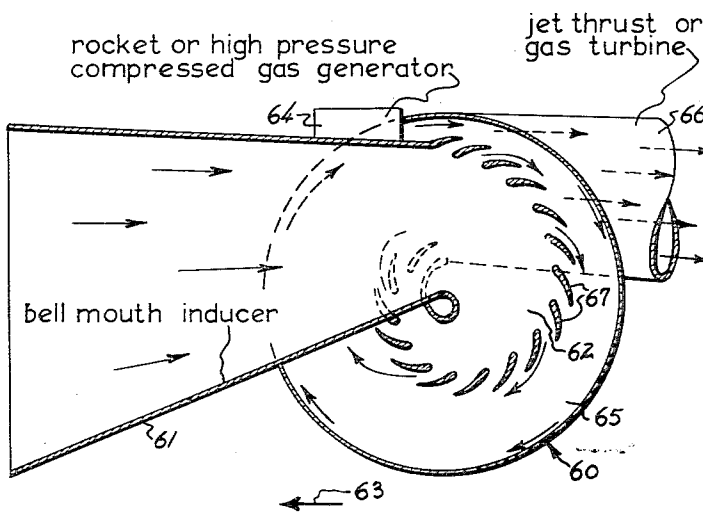
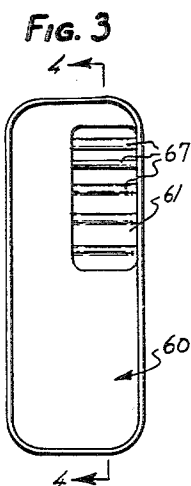
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3 Sheets-Sheet 2



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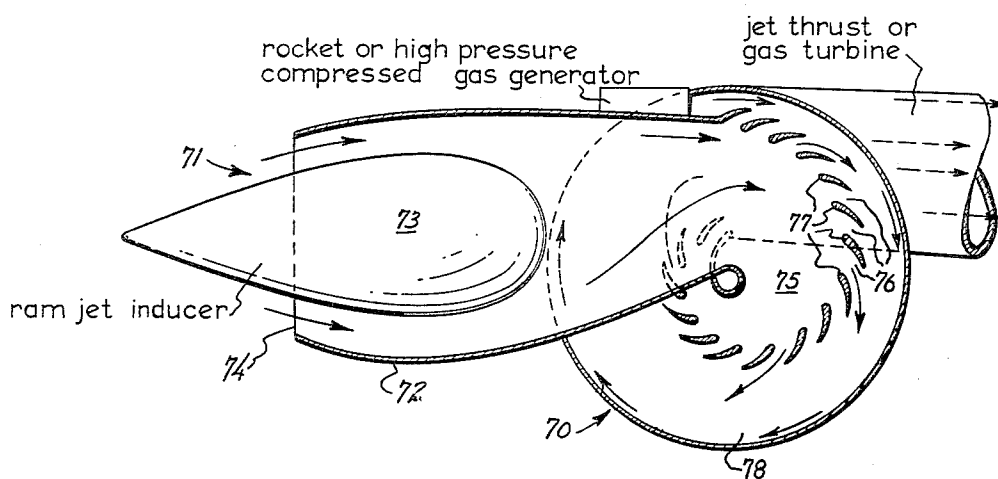
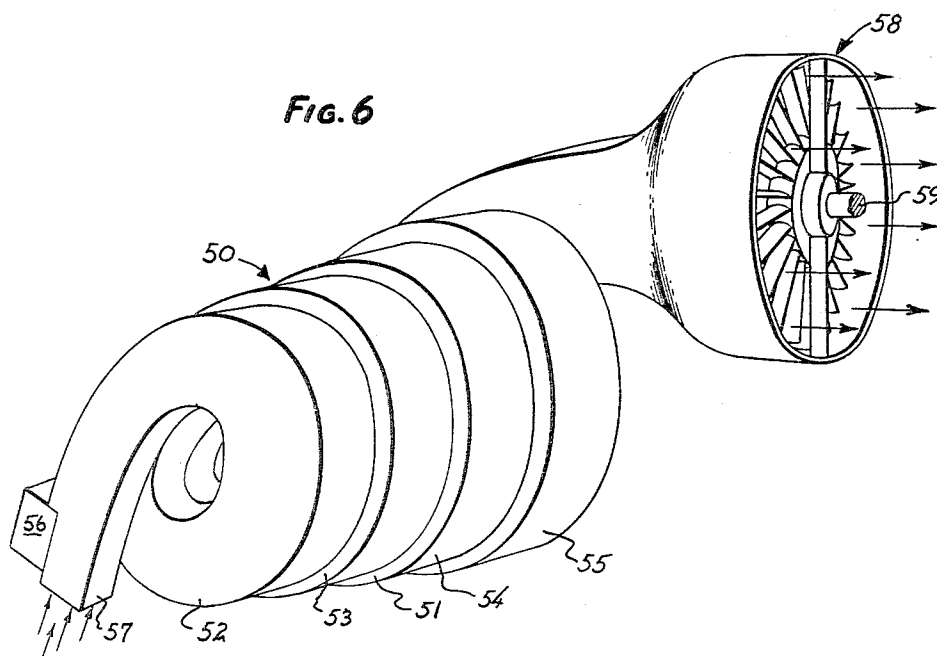
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3 Sheets-Sheet 3



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This invention relates to a novel gas pump of the jet type and to the combination therewith of a gas turbine. In this new pump the gas flow is directed along a spiral helix, i.e., a helix whose diameter increases as its axial length increases. As a result, the pump provides a spiral pumping action resembling that of a whirlwind in nature.

A high-velocity, low-mass flow jet stream of gas (produced by a high-pressure gas generator, a rocket, or any other means) is introduced into a radially outer, spiral-helix channel of a housing. A low-velocity, high-mass-flow gas stream is simultaneously introduced into a radially inner channel of the same housing. The inner and outer channels are separated by a series of air-foil-shaped inducer vanes marking the outer periphery of the inner channel and the inner periphery of the outer channel. Passages between the vanes join the inner and outer channels. The spiral-helical flow of the high-velocity jet in the outer channel produces a centrifugal force absent from conventional jet pumps. Except for a thin boundary layer caused by skin friction with the radially outer wall of its outer channel, the jet gases with the highest kinetic energy are centrifugally forced to flow at the largest radius. As a result, a reduced pressure is produced on the radially outer surface of the airfoil vanes, and low-velocity gas is therefore drawn from the inner channel through the inter-vane passages into the outer channel. The cross-sectional area of the outer channel increases gradually and continually along its path, to accommodate the gradual and continual accretion of gas into it, while the cross-sectional area of the inner channel gradually and continually decreases for the same basic reason.

The airfoil vanes thus may also be considered as inducer nozzles. They are shaped to provide a streamlined flow of the low-velocity gases into the high-velocity gas stream. The angle of attack of the vanes is set so that the flow of the high-velocity gases over their radially outer surface tends to produce laminar flow and to sweep away any vortices that may be formed. Thereby, boundary layer control is maintained at the nozzles, enabling efficiencies close to 90%. In other words, the flow from the inner channel is directed by the inducer nozzles to achieve efficient and gradual mixing of the low-velocity gases with the high-velocity gases.

The invention seeks to convert the kinetic energy, $\frac{1}{2} mv^2$, of the high-velocity gases, which have a small mass flow, to impart substantial velocity to a large mass of low-velocity gas. For example, if it were possible to attain 100% efficiency, a jet stream with a mass flow of one pound per second and a velocity of 6000 feet per second could pump fifteen pounds per second of air from zero velocity up to a velocity of 1500 feet per second. At 90% efficiency, the velocity would still be 1350 feet per second.

The mixed gases from the pump exhaust may be used as jet thrust for an airplane or other vehicle. Jet thrust T is given by the equation $T=mv./g$. Using the figures in the preceding paragraph at 100% efficiency, the original gas jet would have a thrust of about 186 pounds per sec-

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ond, while the mixed mass would have a thrust of about 745 pounds per second. At 90% efficiency, the pump of this invention thus may impart almost four times as much thrust as the initial jet. Therefore, for subsonic or low transonic speeds the propulsive efficiency of the exhaust gases from my cyclonic jet pump will be greater than the propulsive efficiency of the high velocity jet.

A significant feature of my invention is that a high temperature, high velocity gas jet may be used to pump in cool air and, mixing with it, provide a large mass of cooler gas at appreciable velocity. So the mixed exhaust gases from this pump may be expanded through a gas turbine made from non-strategic material, since the temperature of the exhaust gases may be lowered to less than 1000° F. Moreover, this novel cyclonic pump has no rotating parts and so is not subject to substantial centrifugal stresses as are a gas turbine and rotating compressor. The cool air in the inner chamber is always acting to cool the airfoil vanes; so they are not subject to severe temperature stress problems. The pump housing has only to support the centrifugal force of the high velocity jet, and both the housing and the combustion chamber whence the jet issues may be cooled by gas or liquid to a temperature low enough to assure a good stress life.

A free-piston compressed gas generator of the type illustrated in my application Serial No. 705,469 filed December 24, 1957, may be used as the source of the high-velocity gas jet. When such a generator is compounded directly with a gas turbine, the greatest efficiency and maximum power output are obtained when the pressure and temperature of the gas fed to the high-pressure turbine are as high as practical. However, maximum practical combustion temperature is limited because excessive temperatures shorten the working life of the turbine rotor blades. Similarly, the maximum practical pressure is limited by the number of stages which are practical, by the length of the blades, and by the ratio of their length to their tip clearance. The practical limits of the maximum velocity at which the hot gases from a high-pressure combustion chamber can be expanded through a nozzle depends upon the tip velocity of the turbine rotor blades, and this tip velocity depends upon the blade temperature and the allowable working stress of the blades at this temperature for the design life. For a small turbine of 200 horsepower or less, a pressure ratio of 10 to 1 or less will give the most economical and practical turbine design, and the combustion temperature should not be greater than 1600° F. if the turbine is to have a good stress life.

In a turbine engine employing my new cyclone pump the combustion temperature may be much higher, because the pump housing may be air-cooled and because the high-temperature gases are cooled by mixture with a cool, low-velocity airstream before they reach the turbine. The combustion temperature may be close to the stoichiometric combustion temperature, which is around 5000° F. for most of the fossil chemical fuels, and the temperature of the mixed gases just before they expand through the turbine rotor blades may be reduced to 1500° F. or less.

Other objects and advantages of the invention will appear from the following description of some preferred embodiments thereof.

In the drawings:

Fig. 1 is a view in elevation and in section of a power plant incorporating the principles of the present invention and comprising a jet pump through which a compressed gas generator and combustion chamber is connected to a turbine. The inlet portion to the compressed gas generator and combustion chamber is shown diagrammatically.

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Fig. 2 is a view in section taken along the line 2—2 in Fig. 1.

Fig. 3 is a view in end elevation of a modified form of jet pump embodying the principles of the invention.

Fig. 4 is a view in section taken along the line 4—4 in Fig. 3.

Fig. 5 is a view similar to Fig. 4 of another modified form of jet pump of this invention.

Fig. 6 is a perspective view, somewhat diagrammatic in form, of a power plant similar to that shown in Fig. 1 in that it combines a turbine with a jet pump embodying my invention but differing in that there are more turns of the spiral helix.

The jet pump 10 of Figs. 1 and 2 comprises a housing 11 providing within it a spiral-helical, annular, outer chamber 12 and a similar annular inner chamber 13 lying radially inwardly of the chamber 12. Dividing the chambers 12 and 13 is a circumferential cascade of vanes or inducer nozzles 14 of the airfoil type. The vanes 14 are preferably constructed with their trailing edges 15 almost tangential to the flow around them so as to lead gas from the inner chamber 13 to the outer chamber 12 almost tangentially, thereby reducing eddy flow and preventing the formation of vortices at these points. The vanes 14 are spaced apart to provide nozzle passages 16 between them connecting the two chambers 12 and 13. Thus the outer chamber 12 may be considered as having a U-shaped wall with side portions 17 and 18 and a radially outer peripheral wall 19 (see the bottom of Fig. 2). Similarly, the inner chamber 13 may be considered as having a U-shape with a radially inner peripheral wall 20 and side walls 21 and 22, although the side walls 17 and 21 are actually the same piece of material, as are the side walls 18 and 22.

An inlet 23 leads into the inner chamber 13, and the chamber 13 gradually decreases in cross-sectional area until it is finally non-existent, since all the gas from the inner chamber 13 is drawn into the outer chamber 12. The outer chamber 12 has an inlet 25, preferably comprising a nozzle leading from a combustion chamber 26 of a compressor 27. In place of a compressor and combustion chamber, a rocket may be used to produce high pressure gases at a high temperature that will flow through the nozzle 25.

To prevent overheating the outer wall 19 of the outer chamber 13, a cooling duct 30 may be provided. The duct 30 may have its inlet 31 at its portion of largest radius and an outlet 32 at its portion of smallest radius, and the outlet may either lead into the atmosphere or may empty into the outer chamber (see Fig. 1).

The outer chamber 12 has an outlet 33 which, in the embodiment shown in Fig. 1, leads into or comprises the inlet for a turbine 35 having a distributing baffle 36, a turbine shaft 37 and a series of blades 38 mounted on the shaft 37 and comprising the rotating turbine element. Guide vanes 39 are also preferably provided. Thus the power from the gas leaving the outer chamber 12 may be used to rotate the turbine 35 either on an aircraft or other vehicle or in a stationary plant. In place of powering a turbine, the gas may instead be used for direct jet thrust, if desired.

In operation of the device of Figs. 1 and 2, the high-pressure compressor or rocket 27 provides a high velocity pumping fluid, usually at quite a high temperature. Atmospheric air may enter the compressor 27, be compressed, be discharged into the combustion chamber 26 where fuel is added and burned to heat the gases, and then pass through the nozzle 25 at the inlet to the outer chamber 12. This nozzle 25 may be a supersonic one, if desired. The high-velocity gases from the nozzle 25 are then forced to spiral clockwise in the spiral helical chamber 12, whose radius increases along the flow path, so that at every succeeding incremental portion the radius is larger. Also, the cross-sectional area of the chamber 12 is greater at each incremental stage, to accommodate

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the low-pressure gas which is taken in through the passages 16.

Low-pressure gas is drawn in to the outer chamber 12 from the inner chamber 13, because the high-velocity gases in the outer chamber 12 are forced to spiral and therefore are under high centrifugal force. Since the centrifugal force pushes the gas molecules toward the largest turning radius, the inner radius of the outer chamber 12 is a low-pressure or suction area. The low pressure on the radially outer surfaces 40 of the airfoil vanes 14 and the high velocity of the gas flow around and past them sucks in air through the nozzles or passages 16 between the airfoil vanes 14. Due to the particular airfoil shape of the vanes 14, the discharge is directed tangentially into the outer chamber 12 so that it can be mixed efficiently with the high velocity gases in a substantially parallel flow which tends to sweep away any vortices that might be produced.

As the air is pumped in from the low-pressure inner chamber 13, the total velocity is reduced but the mass flow is increased by an amount which much more than compensates for this and results in significant net increases in the thrust of the total mass. While the discharge from the exhaust 33 of the outer chamber 12 may be used as desired, in the embodiment shown in Fig. 1 it is expelled through the turbine 35 where its large momentum—a result of using the kinetic energy of the jet gas to impart considerable velocity to a large mass—powers the turbine 35. Moreover, the turbine blades 38 need not be made of any critical or strategic materials, since the temperature of the gases passing through the outlet 33 can easily be brought down to a level where normal turbine materials can accommodate it. At the turbine 35 the gases flow through nozzles or guide vanes 39 and are directed into gas turbine buckets 38 where they produce shaft power on the shaft 37.

Meanwhile the outer wall 19 of the chamber 12 may be cooled by air (or water or other fluid) flowing through the outer duct 30. The exhaust for the cooling air may be used as desired. In this configuration the cooling air flows counter to the pump air; so it has a regenerative action and may be a bypass from the channel of the outer chamber, as shown, or it may come from an auxiliary cooling fan or pump.

Although only one helical loop is shown in Figs. 1 and 2, so that the total path lies between 360° and 720°, the turbine engine 50 of Fig. 6 shows an embodiment where a pump 51 provides several loops 52, 53, 54, and 55 between the inlets 56 and 57 and the turbine 58 with shaft 59, so that the total path is much greater than 720°. There may be as many loops as desired, and the increase rate of the radius of the spiral-helix may be related in all instances to the desired conditions for which the unit is designed.

Figs. 3 and 4 show a modified form of the invention. The drawing is simplified by omitting the cooling chamber and gas turbine as shown, although they may (or may not) be present. Here, a jet pump 60 of this invention has a bell-mouth inducer 61 for the inner chamber 62, which is preferably used when air is taken in at the inlet at subsonic speeds. For example, the bell-mouth inducer 61 may scoop in air from the progress of an airplane moving in the direction of the arrow 63, and if the speed of the airplane is lower than the speed of sound, an induced subsonic air current will be taken in. As it flows through the bell mouth 61, the air velocity is gradually increased and it is then directed into the inner chamber 62. Thence it is combined with and speeded up by the high-pressure supersonic hot gas from the compressor 64 moving in an outer chamber 65 to the outlet 66. The area variation in the ducting is selected by continuity of flow so that the tangential velocity in the ducting at the entrance of the airfoil nozzles 67 gives the most efficient flow through them.

Fig. 5 shows another modified form of pump 70 of this

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invention, including a ram jet inducer 71 combining an intake tube 72 with an inducer nacelle 73 mounted therein. This is preferably used when the gas being taken in is at supersonic flow. The gas at the inlet 74 through the throat area captures the ram pressure, reducing the velocity to a value which gives an efficient flow through the inner air ducting 75 into the nozzles 76 between the airfoils 77 and into the outer chamber 78. Otherwise, the operation is the same as that previously shown.

To those skilled in the art to which this invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the spirit and scope of the invention. The disclosures and the description herein are purely illustrative and are not intended to be in any sense limiting.

I claim:

1. A jet pump having a housing providing an outer spiral-helical chamber and an inner chamber; and a series of spaced-apart vanes between said chambers, said outer chamber having an inlet for high-velocity gas at one end where its outer radius is smallest and an outlet at its other end where its outer radius is largest, said inner chamber having an inlet for low-velocity gas and a terminus, so that the high-velocity gas in said outer chamber draws in through said vanes and mixes with itself low-velocity gas from said inner chamber to give a large mass of medium-velocity gas.

2. A jet pump having a housing providing an outer spiral-helical chamber having an inlet and a similar inner chamber; and a series of vanes dividing said chambers so that said outer chamber increases in cross-sectional area and in its outer radius between said inlet for high-velocity gas and an outlet and so that said inner chamber decreases in cross-sectional area between an inlet for low-velocity gas and a terminus, the centrifugal force of said high-velocity gas in said outer chamber causing a low pressure on said vanes and drawing in and mixing with itself low-velocity gas from said inner chamber to give a large mass of gas with a velocity higher than that of the low-velocity gas at its inlet.

3. The pump of claim 2 having a cooling duct surrounding the outer periphery of said outer chamber.

4. The pump of claim 3 wherein said cooling duct has an inlet for cool fluid adjacent said outlet and has an outlet into said outer chamber adjacent said terminus.

5. The pump of claim 2 wherein said spiral-helical outer chamber extends for between 90° and 720°.

6. The pump of claim 2 wherein said spiral-helical outer chamber extends for more than 720°.

7. The pump of claim 2 wherein said vanes are shaped as airfoils with radially outer trailing edges approaching a path tangential to the path of gas adjacent them in said outer chamber.

8. The pump of claim 2 wherein the inlet to said inner chamber comprises an airscoop bell-mouth inducer.

9. The pump of claim 2 wherein the inlet to said inner chamber comprises a ram jet inducer.

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10. A jet pump having an annular housing providing a radially outer annular spiral-helical chamber and a radially inner annular chamber along the same helix as said outer chamber, and a circumferential cascade of airfoils between the chambers spaced to provide passages joining said chambers, said outer chamber increasing in cross-sectional area and in its outer radius between an inlet for high-velocity gas and an outlet, said inner chamber decreasing in cross-sectional area between an inlet for low-velocity gas and a terminus, the centrifugal force of said high-velocity gas in said outer chamber causing a low pressure in the area of said airfoils and drawing in and mixing with itself low-velocity gas from said inner chamber to give a large mass of gas with a velocity higher than that of the low-velocity gas at its inlet.

11. The pump of claim 10 wherein said housing provides a cooling duct surrounding the outer periphery of said outer chamber along the same helix having a flow direction opposite to that of said outer chamber between an inlet at its largest outer radius and an outlet at its smallest inner radius.

12. The pump of claim 11 wherein said outlet of said cooling duct empties into said outer chamber.

13. The pump of claim 10 wherein said airfoils have trailing edges tangential to the flow thereadjacent in said outer chamber.

14. A jet pump comprising a housing providing an outer annular spiral-helical chamber and a similar inner annular chamber; an annular cascade of separated airfoils dividing said chambers from each other, said outer chamber having an inlet and an outlet and increasing in cross-sectional area and in its outer radius between said inlet, and said outlet, said inner chamber having an inlet and a terminus decreasing in cross-sectional area between said inlet and said terminus; a nozzle; a source of high-temperature, high-pressure gas connected to said inlet of said outer chamber through said nozzle; and air intake means connected to said inlet for said inner chamber, the centrifugal force of said high-velocity gas in said outer chamber causing a low pressure at said airfoils and drawing in and mixing with itself gas from said inner chamber to send a large mass of gas cooler than that entering said nozzle with a momentum higher than that of the gas leaving said nozzle.

15. The pump of claim 2 having a source of pressure fluid connected to the inlet to said outer chamber, said outer chamber inlet forming the outlet from said source of pressure fluid.

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