Jan. 13, 1959 M. BERCHTOLD 2,867,981

AERODYNAMIC WAVE MACHINE FUNCTIONING AS A COMPRESSOR AND TURBINE

Filed May 9, 1956 3 Sheets-Sheet 1

FIG. 2.

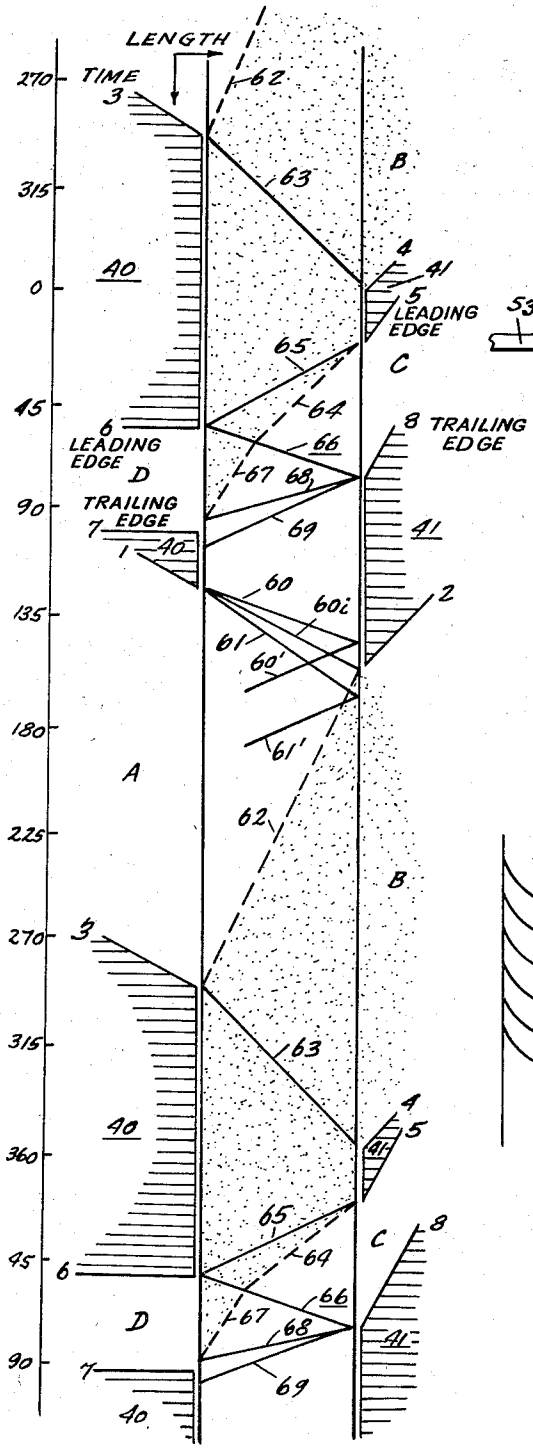


FIG. 1.

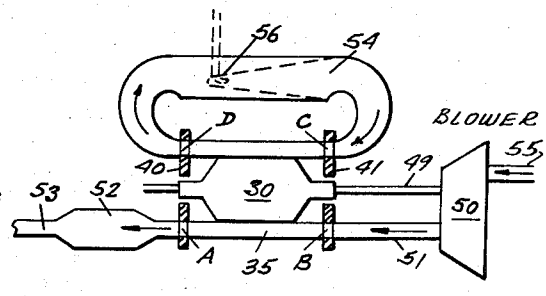
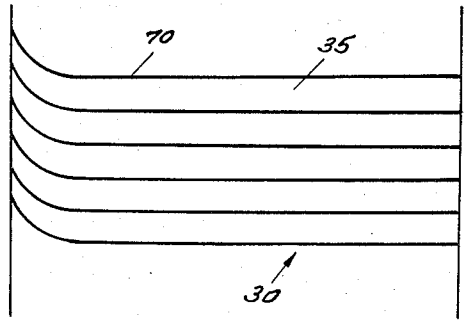


FIG. 3.



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AERODYNAMIC WAVE MACHINE FUNCTIONING AS A COMPRESSOR AND TURBINE

Filed May 9, 1956 3 Sheets-Sheet 2

FIG. 2a.

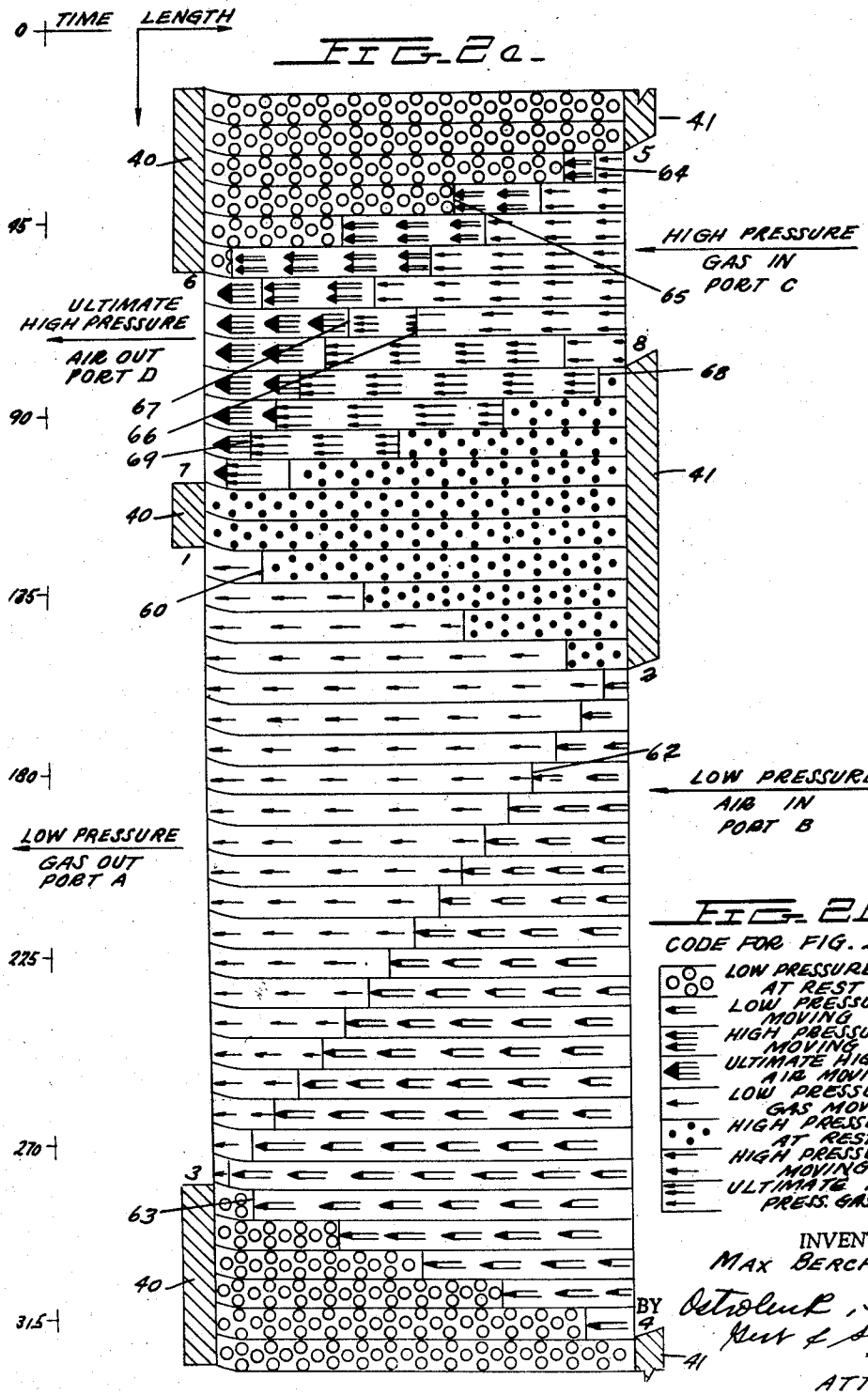


FIG. 2b.

CODE FOR FIG. 2a

- LOW PRESSURE AIR AT REST
- LOW PRESSURE AIR MOVING
- HIGH PRESSURE AIR MOVING
- ULTIMATE HIGH PRESS. AIR MOVING
- LOW PRESSURE GAS MOVING
- HIGH PRESSURE GAS AT REST
- HIGH PRESSURE GAS MOVING
- ULTIMATE HIGH PRESS. GAS MOVING

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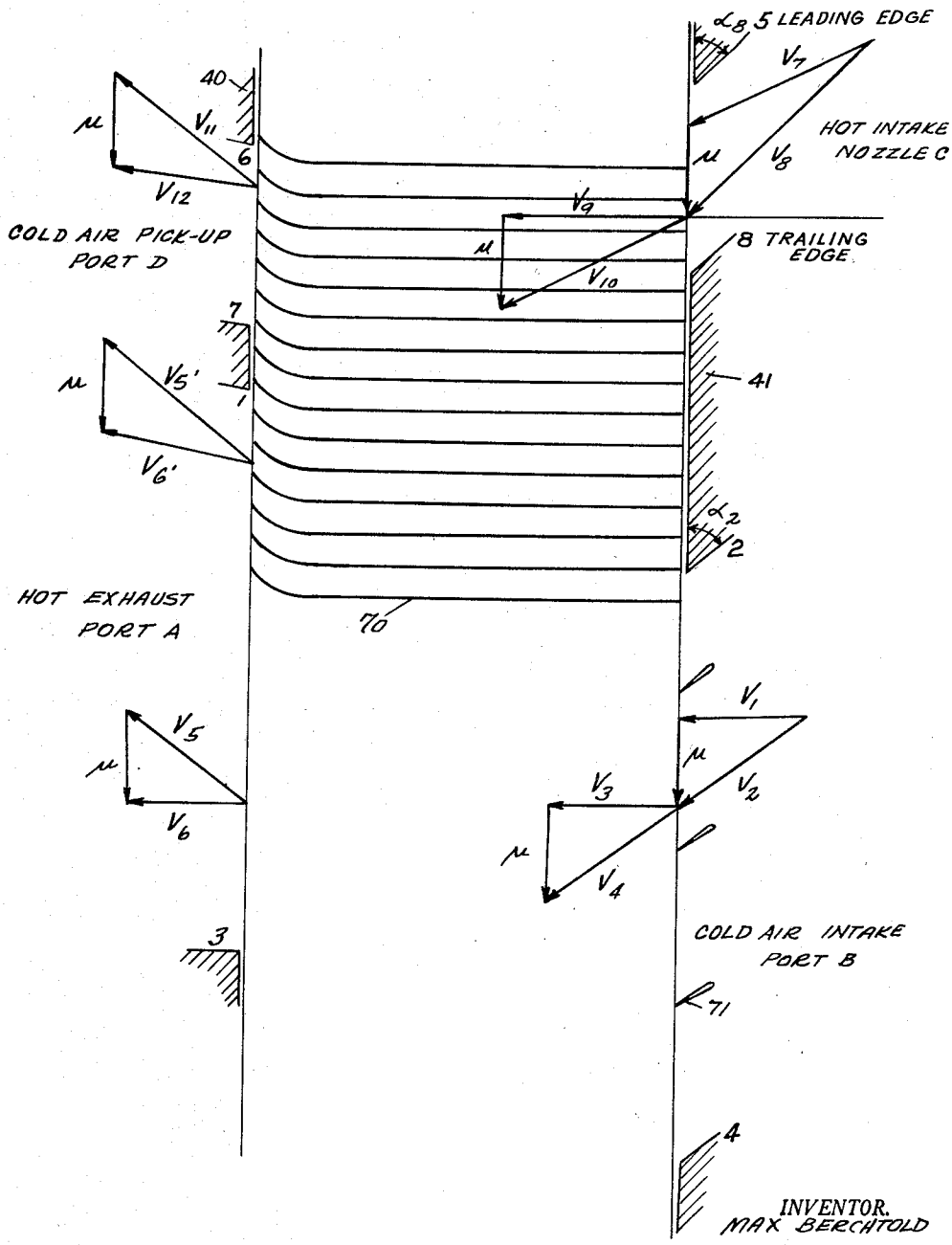
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AERODYNAMIC WAVE MACHINE FUNCTIONING AS A COMPRESSOR AND TURBINE

Filed May 9, 1956 3 Sheets-Sheet 3

FIG. 4.



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United States Patent Office 2,867,981
Patented Jan. 13, 1959

2,867,981

AERODYNAMIC WAVE MACHINE FUNCTIONING AS A COMPRESSOR AND TURBINE

Max Berchtold, Paoli, Pa., assignor to I-T-E Circuit Breaker Company, Philadelphia, Pa., a corporation of Pennsylvania

Application May 9, 1956, Serial No. 583,647

3 Claims. (Cl. 60—39.45)

My invention relates to an apparatus to perform the conventional thermo-dynamic cycle of a jet engine and is more particularly directed to a novel combination of compressors, combustion chambers and turbines, wherein the turbine rotor performs part of the air compression by means of wave interaction, thereby permitting higher gas temperatures at the turbine on account of the cooling effect of the air.

In the prior art arrangement, a jet engine for aircraft propulsion is comprised of a compressor, one or more combustion chambers and a turbine. The compressor feeds compressed air into the combustion chamber where the air is heated and enters the turbine as hot gas. The shaft power produced in the turbine is utilized to drive the air compressor. The energy still contained in the gas leaving the turbine is transformed into kinetic energy in the exhaust nozzle. The jet engine produces thrust due to the change in momentum between the air at the intake and the gas leaving the exhaust nozzle.

However, with the prior art arrangement, a large number of axial flow turbo compressor stages are necessary. Furthermore, the permissible temperature of the gases at the turbine intake is limited. With my novel arrangement, part of the compression, which is done in the aero-dynamic wave engine, also produces shaft power and can be utilized to drive an initial compressor stage.

The fact that in the novel arrangement, the air passes through the rotor acting as a compressor and as turbine, provides effective cooling to the rotor, and therefore, higher gas temperatures do not result in higher rotor metal temperatures.

The aero-dynamic wave machine, the subject of this invention, operates on the principles set forth in my copending application Serial No. 454,774 filed September 8, 1954.

The machine of the instant invention is essentially identical to the described forward cycle machine except the channels of the rotor have curvature and the flow angles of the gas and air entering the rotor are chosen differently. There is one major distinction however inasmuch as there is no compressed air or hot gas by-passed to a turbine or other device. All the hot gas expands going back through the same rotor in which the air had been compressed. In this case, more kinetic energy is available in the exhaust. This makes the cycle most suitable for a jet engine for which the purpose is to produce kinetic energy only.

It will be noted that the aero-dynamic wave machine of my invention is provided with a plurality of channels or cells which are situated on the circumference of the rotor.

In my copending application Serial No. 454,774 filed September 8, 1954, the channels merely serve to separate the hot and cold gases and provide the timing of the compression and expansion waves. The rotor itself does not produce or absorb power except for the function of the bearings and the outside windage of the rotor.

However, with this novel utilization of the aero-dynamic wave principle, the channels have a configuration of turbine blades which thereby permit extraction of shaft power from the gases flowing through the machine. Thus, the device may function as a turbine to deliver shaft power for various purposes.

In the case of a jet engine, this shaft power can be utilized to obtain more thrust at a better fuel consumption by a precompression of the air before entering the aero-dynamic wave machine. The mass flow capacity of the engine increases on account of the higher density of the air and the higher pressure drop in the nozzle gives higher exhaust velocities.

Another possibility of the use of the shaft power in the field of aircraft propulsion is in the drive of a ducted fan or a propeller. This means the mass flow of the precompressed air is higher than the rotor can handle. In this case only, part of the air enters the air intake port, the remaining portion is directly discharged into a jet nozzle. This air can be heated or discharged cold. In the case of a propeller, a scavenging blower is still needed. The pressure which is required in the forward cycle for scavenging is in this case furnished by the shaft driven compressor. The static pressure in the exhaust is lower than the total pressure produced by the shaft driven compressor.

It will be noted that the aero-dynamic wave machine of my instant invention is provided with means whereby the air enters through the air intake, is then compressed in the wave engine rotor and emanates from the air pick-up port. The compressed air will then be heated in one or more combustion chambers. The hot gases leaving the combustion chamber will be supplied to the rotor through the intake nozzle where the gases expand and leave the rotor at the exhaust port. Essentially, the ports are described in my copending application Serial No. 454,774 filed September 8, 1954.

It should be noted that the aero-dynamic wave machine with shaft power extraction of my instant invention has some of the characteristics of the two-stage turbine of my copending application Serial No. 413,610, filed March 2, 1954, now U. S. Patent 2,828,103, issued March 25, 1958, and assigned to the assignee of the instant application. However, in Patent 2,828,103, the primary function of utilizing stationary flow phenomenon is to reduce the pressure between the stages and does not compress any air in the same rotor; the two stage turbine only expands gas, the energy of which is transformed in shaft power. In contra-distinction, the construction of the instant invention simultaneously performs the two functions, namely the direct exchange of energy from one gas to another and the transformation of energy into shaft power.

This turbine effect of my novel aero-dynamic wave machine is achieved by (*a*) a proper flow angle for the air entering the rotor through the air intake port and the proper flow intake angle of the intake nozzle and (*b*) by the proper timing of the channels.

In my novel aero-dynamic wave machine, a hot gas is introduced into the rotor to the hot nozzle and cold air is introduced into the rotor through the air intake port. Hence, the blade channels are alternately subjected to hot and cold gases and, as a result thereof, never reach the extreme high temperatures of the hot gas.

In the prior art arrangement a compressor is feeding air to one or more combustion chambers, the hot gas then expands in a turbine. The maximum temperature of the hot gas entering the turbine is limited by the permissible blade metal temperatures to protect the blades. If high gas temperatures are to be used, it is necessary to provide cooling means to protect the blades. In contra-distinction, my novel device which alternately subjects the rotor blades to hot and cold gases, i. e. forward cycle,

can operate with high temperature gases without damaging the blades. That is, since the turbine action is superimposed to the aero-dynamic wave machine, high gas temperature can be utilized due to the cooling effect of the cold air.

Accordingly, a primary object of my invention is to provide a novel turbine-compressor device operating on nonsteady flow phenomenon wherein one gas expanding exchanges energy to another gas to be compressed and wherein shaft power is extracted due to the particular shape of the blades.

Still another object of my invention is to utilize an aero-dynamic wave machine for a jet engine of an aircraft wherein the wave machine rotor provides shaft power for an air precompressor or a propeller.

Another object of my invention is to provide a novel combination turbine aero-dynamic wave machine wherein automatic cooling of the blades is achieved without the necessity of providing auxiliary cooling means.

These and other objects of my invention will be apparent from the following description when taken in connection with the drawings in which:

Figure 1 is a cross-sectional view of a turbine aero-dynamic wave machine of my invention.

Figure 2 is a representation of the rotor of my novel aero-dynamic wave machine with shaft power extraction laid out in one plane. This figure is a wave diagram illustrating the compression and expansion waves and the interface between hot and cold gas within the rotor.

Figure 2A is a cycle diagram similar to Figure 2 and shows by legend the condition of the air and gas during the various stages.

Figure 2B is a code for the legends of Figure 2A.

Figure 3 is a detailed view of the configuration of the plurality of blades within the rotor which enables my novel device to produce both shaft power and kinetic energy in the exhaust.

Figure 4 is a vector diagram for each port and for the air in the rotor at the high and low pressure portion of the cycle.

Referring to Figure 1, I have shown a cross-sectional view of my novel aero-dynamic wave machine with shaft power extraction. The machine has substantially the same construction as heretofore described in my copending application Serial No. 454,774 filled September 8, 1954. It is comprised of a rotor **30** having a plurality of cells or channels **35** positioned around the outer periphery thereof and extending in a direction substantially parallel to the rotational axis of the device.

The cells **35** have a configuration similar to that shown in Figure 3 so that they will serve a dual function, that is, the curved portion of the blades acts as a turbine within the aero-dynamic wave machine.

In addition to serving as blades for the turbine action of the machine, they also provide the phase angle between the compression and expansion waves in each channel. The rotor **30** is mounted on the drive shaft **49**. The above noted turbine action on the blades will furnish the shaft power to drive the compressor **50**. A small portion of the power is absorbed by bearing friction and windage losses. In order to secure the correct wave timing the rotor speed has to be controlled by the power absorption of the compressor.

The rotor **30** is straddled by stator plates **40** and **41**. The stator plate **40** contains the cold air pickup port D and the hot exhaust port A. The stator plate **41** contains the hot gas intake port C and the cold air intake port B.

The air intake **55** supplies air to the multi-stage compressor **50** which is mechanically driven by the shaft power output of the turbine aero-dynamic wave machine. The air compressed in multi-stage compressor **50** is supplied to the cold air intake port B through the duct **51**.

The entire compressed cold air mass flow from the pick-up port D is supplied to the combustion chamber **54** and is mixed with the fuel injected at **56**. Following combustion within the combustion chamber **54**, the hot gas leaving the combustion chamber is supplied to the hot nozzle intake C. The aero-dynamic wave machine exhausts through the hot exhaust port A to the exhaust duct **52** and thence to the jet nozzle **53** wherein propulsive thrust is obtained.

In Figure 2, I have shown the conditions which exist within the rotor **30**. In this figure, the rotor is laid out in one plane and illustrates the conditions which exist in all portions of the rotor at any location and instant. As the individual cells of the rotor move successively past the ports A, B, C and D, various compression and expansion waves are created with interfaces between different gases. As a result of the compression waves, the gases and their interfaces flow across the channel.

In the view of Figure 2, I have shown the various compressions and expansion waves by solid lines and the various interfaces by dotted lines.

The cells **35** in the rotor **30** are continuously moving past the ports and the closed spaces between the ports. Thus the cycle for the purpose of description may be started at any point. At the left of the diagram of Figure 2, I have provided indicia marked as angular location at the stator plates in direction of the rotation of the rotor **30**. Thus, for example, assuming that the cycle starts at 110°, the gas within the cell **35** will be stationary and both its left and right-hand ends will be closed off by the stator plates **40** and **41**.

The description of the cycle is arbitrarily started when the hot gas is trapped within the cell **35** at an elevated pressure. As the cell **35** continues to move from the 110° point to the 125° point, its left end is opened at the leading edge **1** of the hot exhaust port A where the static pressure is lower than the initial static pressure within the cell. As a consequence thereof, a series of expansion waves **60**, **60*i***, **61** of small amplitude will start to pass through the cell, all starting simultaneously at the leading edge **1**. However, each wave will travel at a velocity slower than the preceding wave so that the zone covered by the waves becomes progressively wider. This phenomenon is clearly set forth and described in my copending application Serial No. 454,774, filed September 8, 1954, and will determine the proper location of the leading edge **2** of the cold air intake port B.

As the expansion waves **60**, **60*i***, **61** traverse the cell **35** toward the right hand end of the rotor, they will continue to diverge so that there will be a plurality or bundle of waves defined in the area outlined by these two waves **60**, **61**. The initial wave **60** will be the first to impinge upon the closed end at the right of the cell **35** and hence, the reflected expansion wave **60'** creates an even lower pressure at the close off plate **41**. As the next successive waves subsequently impinge upon the closed end **41** of the cell **35**, the pressure created by the reflected waves drops until it reaches the pressure in the air intake port B. The leading edge **2** is positioned within the circumference of the rotor where the pressure behind the reflected wave is equal to the pressure supplied through the air intake port B. Thus, as seen in Figure 2, the intermediate wave **60*i*** would have a reflected wave which creates a pressure equal to the pressure in the air intake port B and hence, no reflected wave occurs for the intermediate wave **60*i***. The last group of waves within the bundle, that is, preceding wave **61** and including wave **61** will have a reflected wave with a pressure which could be lower than the pressure of the air supplied through the air intake port B. However, since these reflected waves arrive after the cell **35** has passed the leading edge **2**, the right hand end of the cell is now open and hence, the pressure in the port is higher than the pressure would be behind the reflected wave **61'** which accelerates the air into the rotor channels. Hence, the reflected wave **61'** is a compression wave. Thus, the right hand end of the cell **35** at ap-

proximately 150° rotation is completely opened by the leading edge 2 of the air intake port B to receive the precompressed cold air from the scavenging blower 50.

Since the pressure in the cells 35 is lower than the total pressure in the cold intake port B, the cold air will flow from port B into the cell and displace the hot gases which were contained within the cell.

The interface between the hot and cold gas within the rotor 35 as it passes through the channel between the 165° point and the 290° point is indicated by the interface line 62. It will be noted that the cold air is accelerated. This means the interface line 62 is curved within the range of the intermediate separation wave 60*i* and the last expansion wave 61. That is, the reflected waves from these initial expansion waves continuously and progressively cause an increase of intake velocity of the scavenging air from the port B.

At approximately the 290° point of rotation, all the hot gas has been removed from the channel 35. At this time, the cell is closed by the trailing edge 3 of the hot exhaust port A.

As heretofore noted in connection with Figure 1, the hot exhaust port A is connected to the exhaust duct 52 which in turn supplies hot exhaust gas to the jet nozzle 53. Thus, the compressed air from the multi-stage compressor 50 supplied to the cold air intake port B will force these hot gases out of the rotor of the aero-dynamic wave machine as shown by the interface 62.

The gases within the cell 35 which were supplied to the machine from the compressor 50 through the cold air intake port B will suddenly be stopped as they impinge upon the stator 40 between the trailing edge 3 of port A and the leading edge 6 of port D. The kinetic energy of these gases which have been traveling to the left is suddenly transformed into pressure to thereby create a shock wave 63 which will travel upstream, that is, in opposite direction to the flow of the gases.

The gases ahead of the shock wave 63 will be at their original pressure and velocity whereas the gases behind the shock wave 63 will be at an elevated pressure and at rest. The compression wave 63 is a distinct wave which changes the pressure and velocity of the gases discontinuously.

The ports in the stator plates 40 and 41 are so constructed and the speed of the rotor is so determined that the compression wave 63 reaches the right-hand end of the cell 35 as the cell reaches the trailing edge 4 of the air intake port B. This is at approximately the 360° rotation point of the rotor 30.

As the cell moves further beyond the 360° or zero degree point, the gases trapped within the cell 35 will remain stationary as both ends of the cell are closed off by the stator plates 40 and 41. After further rotation of approximately 30°, the channel reaches the leading edge 5 of the hot nozzle intake C. Since the pressure of the hot gas is higher than the pressure of the air in the channel, the hot gas enters the channel creating a compression wave 65. The hot gas entering the rotor through the hot nozzle intake C displaces the air in the channel.

The interface between the hot and cold gases is indicated by the interface line 64. The compression wave 65 which is initiated at the leading edge 5 of the hot gas nozzle port C at the 30° point travels through the cold air.

The air between the interface line 64 and the compression wave line 65 represents the compressed portion.

As the cell 35 continues its downward rotation, its left-hand end will be opened at the pickup port D at opening edge 6.

Since the static pressure existing in the pickup port D is higher than the pressure of the air compressed by the compression wave 65 there will be reflected a new compression wave 66 at the leading edge 6 of the cold air pickup port D. This compression wave will travel upstream and represents a deceleration of the flow velocity of the gases within the cell 35.

The deceleration of the gases within the cell is indicated by the change in the slope of the interface line. Thus, for example it will be seen that the interface 67 has a steeper angle than the interface 64 thereby indicating that the gases have been decelerated by the reflection wave 66. The compression wave 66 by decelerating the gas within the cell will transform the energy thereof to a higher pressure and density which will then be received through the cold pickup port D.

That is, since the total pressure in the cold air pickup port D is higher than the total pressure in the hot gas nozzle port C because of the pressure differential, power can be extracted from the gases. The utilization of this available power can be achieved either by a separate turbine or by my novel arrangement. That is, utilizing the compression of the rotor channels so that a turbine effect will be created.

It will be noted that when an aero-dynamic wave machine is provided with a separate prime mover for the timing of the ports and the rotor, such as shown in my copending patent application Serial No. 454,774, filed September 8, 1954, the energy imparted to the gases within the rotor is extracted through the pickup port D. Thus, in the prior art arrangement the initial or static pressure at the port D is equal to the pressure at the nozzle C. Under these conditions, there will not be a reflection wave or shock wave 66. In contra-distinction, the apparatus of my instant invention provides an initial static pressure at the pickup port D which is higher than the pressure at the nozzle C. That is, there is no output cycle or operation at the port D, hence, the movement of the cell 35 past the 45° point wherein its left end is opened by the leading edge 6 to expose the low pressure in the cell 35 to the high static pressure in the pickup port D will create a reflection of the wave 65 in the form of the shock wave 66. Thus, as heretofore noted, this pressure differential between the nozzle C and the pickup port D represents available energy which can be extracted by means of proper configuration of the channels and the ducts, as illustrated in Figure 3.

Accordingly, the rotor becomes a driving unit. An external prime mover is necessary for starting. The power derived as a result of the above noted turbine action is utilized to drive the air precompressor. The rotational speed is a result of the power balance between the absorbed power of the compressor and the produced shaft power of the turbine. In order to secure proper wave timing, this speed has to be controlled. The power produced can be affected by variable guide vanes at the air intake port B. Such a device is described in copending application Serial No. 463,953 filed October 22, 1954.

The trailing edge 8 of the nozzle C is preferably positioned at a point on the circumference so that the shock wave 66 reaches the right hand end of the cell 35 at the time the cell reaches the trailing edge 8. The trailing edge 7 of the pickup port D is positioned with respect to the trailing edge 8 of the nozzle C so that all of the cold air within the rotor is passed out through the pickup port D prior to the time that the left hand edge of the cell 35 is closed by the stator 40.

As best seen from the wave diagram in Figure 2, the interface 67 represents the separation between the cold air on the left and the hot gas on the right. The trailing edge 7 of the pickup port D coincides with the end of the interface line 67 indicating that all the cold air has been extracted from the cells 35. As the right hand end of the rotor is closed by the trailing edge 8 of the nozzle, expansion waves are created. These waves which are in the form of a bundle defined by the waves 68 and 69 decrease the pressure in the cells 35.

The closing of the pickup port D is inter-related to the closing of nozzle C, so that only the latter portion of

the bundle of expansion waves defined by **68** and **69** arrives at the left hand at the closed off stator plate **40**.

As the cell travels from the 110° point to the 125° point it will have both ends closed off by the stator plates **40** and **41**. In this time the hot gas is at medium pressure at rest. Thus, the cycle will thereafter be repeated in the manner heretofore described.

The trailing edge **8** of the nozzle C does not necessarily have to be positioned on the circumference at the point where the shock wave **66** reaches the right hand end of the cell **35**, thus, if the parameters of the aerodynamic wave machine do not permit the location of the trailing edge **8**, as seen in Figure 2, its location either before or after the arrival of shock wave **66** will not substantially affect the operation of the apparatus.

Figure 3 illustrates the configuration of the plurality of blades within the rotor **30**. It is this configuration of the blades which produces shaft power, since the blades not only establish the phase relation of the waves in adjacent channels but also act as turbine blades.

Figure 4 also illustrates the angles of the various ports which are necessary to direct the flow at the required angle into the rotor, or receive the gas leaving the rotor at the correct flow angle.

The following designations are used in the drawings to represent the various quantities indicated:

U=the tip speed of the rotor **30**.

V_1=the relative air velocity ahead of the rotor within the cold air intake port B.

V_2=the absolute air velocity ahead of the rotor in the cold air intake port B (nozzle velocity).

V_3=the relative air velocity within the rotor in the low pressure cycle.

V_4=the absolute air velocity within the rotor in the low pressure cycle.

V_5=the relative gas velocity at the hot exhaust port A.

V_6=the absolute gas velocity at the hot exhaust port A.

V_7=the relative gas velocity ahead of the rotor at the hot intake nozzle C.

V_8=the absolute gas velocity ahead of the rotor at the hot intake nozzle C.

V_9=the relative gas velocity in the rotor in a high pressure cycle.

V_{10}=the absolute gas velocity in the rotor in a high pressure cycle.

V_{11}=the relative air velocity at the cold air pickup port D.

V_{12}=the absolute air velocity at the cold air pickup port D.

The configuration of the blades **70** and the location of the various ports as well as the flow angles in the ports is determined by means of successive approximation. A typical cycle which is the result of such an analysis is shown in Figure 2. A direct solution is not possible since the available energy from the cycle is not necessarily equal with the shaft energy that can be extracted from the rotor **30**. Corrections of the hot nozzle duct angle α_8, the rotor speed μ or the curvature of the blades **70** are necessary until the balance between available and extracted energy is reached. With the known shaft power the precompression of the air in the blower **70** (Fig. 1) can be determined. For the wave engine cycle only the pressure ratio and the temperature ratio between the condition in the intake and at the combustion chamber had been established.

The absolute pressures and temperatures in the air intake as well as in the combustion chamber can only be determined when the available power for precompression of the air is known.

The rotational speed of the rotor is selected considering the centrifugal and bending stresses in the blades. The wave diagram of Figure 2, which in the result of an analysis based on the method of characteristics assuming the cycle pressure ratio, the temperature ratio, the clearances between the rotor **30** and the stators **40** and **41** and the corrections for heat transfer, determines the flow velocities in the rotor channels. These represent the relative velocities V_3, V_5, V_7, V_{11}. The absolute rotor velocities result from a vectorial addition of the relative velocities with the circumferential velocity U.

The turbine action, which is superimposed to the wave engine cycle, is shown by the velocity triangles in Fig. 4. Thus, for example, the right hand side of the blades **70** and channels formed thereby extend in a direction parallel the axis of the rotor **30**. Since we know the magnitude of the relative gas velocity V_3 within the rotor in the low pressure portion of the cycle and also know the magnitude of the absolute velocity V_4 within the rotor is determined. The intake duct angle α_2 as well as the angles of the guide vanes **71** are chosen and the relative velocity V_3 becomes axial. The air enters the channels without angle of attack, which means without exerting a driving or braking torque to the rotor.

With a practical degree of blade curvature near the exit, the direction of the relative gas velocity V_5 at the exhaust port A is determined. Since the circumferential speed U is known and the relative gas velocity V_5 is known, it is possible to determine the magnitude and direction of the absolute gas velocity V_6 at the exhaust port A. The relative velocity V_5 of the gases leaving the rotor at port A is highest near the edge **1**, due to the expansion waves **60** and to **61**. As these waves reflect at the intake port, the exhaust velocity decreases. Fig. 4 shows two typical exhaust velocity triangles for the exhaust port A. Due to the curvature of the blades, more energy is being extracted from the high speed gases. This is a desirable condition since this helps to obtain a more uniform absolute velocity distribution into the collector or afterburner **52**.

In the high pressure cycle, the magnitude and direction of the relative gas velocity V_9 is known and hence the absolute gas velocity V_{10} in the rotor can be vectorially computed as illustrated. In this case, however, the angle α_8 of the absolute velocity V_8 is arranged so that the relative velocity V_9 enters the rotor with an angle of attack. This means the flow has to change direction, thus exerting a driving torque to the rotor. The axial components of the velocity V_7 is equal to the velocity V_8 on account of continuity.

Due to the blade curvature of the blades **70** near the pickup port D, additional torque is exerted on the rotor. The relative air velocity V_{11} in the rotor channels at the pickup port D, which is known as a result of the cycle analysis, is lower than the relative gas velocity V_9 due to the compression wave **66**. The pressure drop from the pickup port D to the nozzle port C represents available energy which is converted into shaft energy. The relative air velocity V_{11} in the port D becomes the absolute velocity V_{12} entering the pickup diffusor.

By integrating the total circumferential velocity components of each of the four ports A, B, C and D, the total available shaft horsepower can be calculated. This magnitude of horsepower is the power which will be utilized to drive the multi-stage blower **50**. Hence, it determines the available absolute pressure for the air, to be delivered at the intake port B. Since the cycle calculations were previously made for an assumed pressure ratio, the absolute pressures are determined throughout the cycle.

The specific thrust (thrust per pound of intake air) can now be calculated if a simple jet nozzle **53** is used or if an afterburner with a jet nozzle is used.

Since all the calculations are made for a unit airflow the actual size of the compressor can be determined in order to obtain the desired thrust.

In the foregoing, I have described my invention only in connection with preferred embodiments thereof. Many variations and modifications of the principles of my invention within the scope of the description herein are

possible. Accordingly, I prefer to be bound not by the specific disclosure herein but only by the appending claims.

I claim:

1. An aero-dynamic wave machine to produce shaft power operating on a forward cycle of instationary flow phenomenon; said aero-dynamic wave machine being comprised of a rotor, a first stator plate and a second stator plate; said rotor having a plurality of blades positioned around the periphery thereof to provide a plurality of channels; said channels being open at each end; said first stator plate being positioned at a first end of said channels and said second stator plate being positioned at a second end of said channels; said first stator plate having a hot exhaust port and a cold air pick-up port; said second stator plate having a cold air intake port and a hot intake nozzle; said cold air pickup port having a higher total pressure than said hot intake nozzle to thereby cause the creation of a reflected compression wave when said first end of one of said channels reaches the leading edge of said cold air pick-up port; said reflected compression wave travelling upstream and decelerating the fluid in said rotor; said hot intake nozzle having a trailing edge which is operatively positioned on the circumference of said rotor with respect to said leading edge of said cold air pick-up port so that said reflected compression wave created at said leading edge of said cold air pick-up port will traverse said one channel and arrive at the opposite end of said one channel during the time said channel passes said trailing edge of said hot intake nozzle; said blades having a configuration to extract the energy transformed by the deceleration of the fluid.

2. An aero-dynamic wave machine to produce shaft power operating on a forward cycle of instationary flow phenomenon; said aero-dynamic wave machine being comprised of a rotor, a first stator plate and a second stator plate; said rotor having a plurality of blades positioned around the periphery thereof to provide a plurality of channels; said channels being open at each end; said first stator plate positioned at a first end of said channels and said second stator plate positioned at a second end of said channels; said first stator plate having a hot exhaust port and a cold air pick-up port; said second stator plate having a cold air intake port and a hot intake nozzle; said ports positioned and construction to close off the first and second end of one of said channels when said rotor is at 0° rotation, one end of said one channel opened to the leading edge of said hot intake nozzle on continued rotation to thereby create a compression wave traveling upstream which decreases the pressure behind it; said hot intake nozzle introducing hot gas into the said one channel; the other end of said one channel opened to the leading edge of said cold air pick-up port upon a continued rotation to thereby create a reflected compression wave due to the pressure differential between said cold air pick-up port and said hot intake nozzle; said hot intake nozzle having a trailing edge which is operatively positioned on the circumference of said rotor with respect to said leading edge of said cold air pick-up port so that said reflected compression wave created at said leading edge of said cold air pick-up port will traverse said one channel and arrive at the opposite end of said one channel during the time said channel passes said trailing edge of said hot intake nozzle; said reflected compression wave effective to decelerate the fluid in said channel to thereby transfer sufficient energy to said blades to drive said aero-dynamic wave machine and provide excess shaft power.

3. An aero-dynamic wave machine to produce shaft power operating on a forward cycle of instationary flow phenomenon; said aero-dynamic wave machine being comprised of a rotor, a first stator plate and a second stator plate; said rotor having a plurality of blades positioned around the periphery thereof to provide a plurality of channels; said channels being open at each end; said first stator plate positioned at a first end of said channels and said second stator plate positioned at a second end of said channels; said first stator plate having a hot exhaust port and a cold air pick-up port; said second stator plate having a cold air intake port and a hot intake nozzle; said hot intake nozzle designed to permit the total pressure therein to be less than the total pressure in said cold air pick-up port, one of said channels having its right end exposed to the leading edge of said hot intake nozzle when its left end is closed off by said first stator plate to thereby create a compression wave in said one channel, said cold air pick-up port having its leading edge partitioned on the circumference of said first stator plate so that the left end of said one channel and said compression wave reach said leading edge simultaneously, a reflected compression wave propogated in said one channel when said left end reaches said leading edge of said cold air pick-up port, said hot intake nozzle having a trailing edge which is operatively positioned on the circumference of said rotor with respect to said leading edge of said cold air pick-up port so that said reflected compression wave created at said leading edge of said cold air pick-up port will traverse said one channel and arrive at the opposite end of said one channel during the time said channel passes said trailing edge of said hot intake nozzle; said reflected compression wave decelerating the fluid in said channel to permit shaft power to be extracted from said aero-dynamic wave machine.

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