June 15, 1948. J. A. JOHNSON 2,443,250

JET PROPULSION UNIT

Filed Dec. 31, 1942

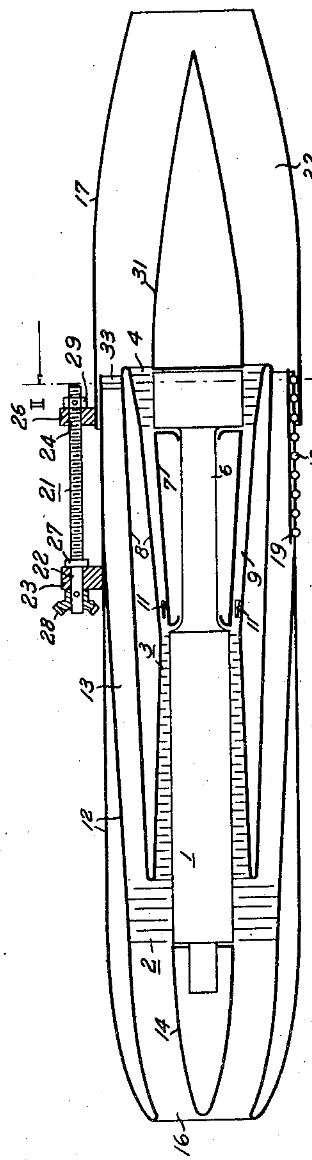

Fig. 1

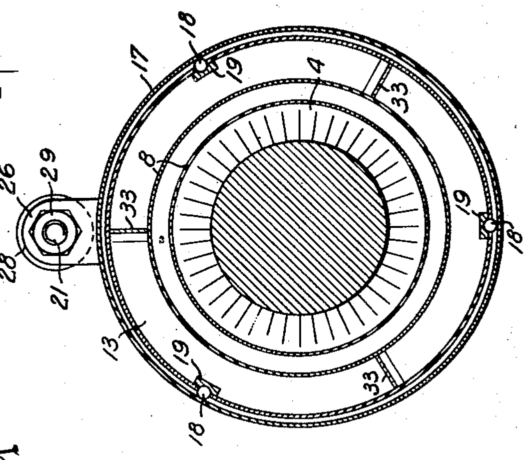

Fig. 2

Inventor
J. A. Johnson
by K.S. Wyman
Attorney

UNITED STATES PATENT OFFICE

2,443,250

JET PROPULSION UNIT

John Algot Johnson, Wauwatosa, Wis., assignor to Allis-Chalmers Manufacturing Company, Milwaukee, Wis., a corporation of Delaware

Application December 31, 1942, Serial No. 470,899

11 Claims. (Cl. 60—35.6)

This invention relates generally to power units and more particularly to jet propulsion apparatus for aircraft and other types of vehicles.

An object of this invention is to improve the construction, performance and efficiency of jet propulsion apparatus utilizing a propulsive jet formed by a plurality of gas streams having materially different temperatures.

Another object of this invention is to provide jet propulsion apparatus embodying elements correlated in a manner effective to increase the temperature and thereby the sound velocity of the propulsive blast without decreasing the efficiency.

Still another object of this invention is to provide jet propulsion apparatus embodying elements correlated in a manner effective to increase the momentum and thereby the propulsive effort of the propelling blast.

In accordance with this invention, one or more of the above stated objects may be accomplished by the provision of apparatus embodying elements correlated to produce a plurality of separate gas streams having materially different temperatures and by combining and expanding said streams under conditions effective to produce a resultant stream propelling jet having a momentum greater than the sum of the momenta of the separate streams after expanding from the same pressure.

More particularly, the present invention is directed toward and has as an object the provision of a jet propulsion unit including compressing, heating, turbine, and expanding nozzle means constructed and combined to produce and deliver to the inlet end of said nozzle means separate gas streams including a hot gas stream which flows through and operates said turbine and a cold gas stream, and including one or more parts or structures, preferably disposed in immediate upstream relation with respect to the inlet of said nozzle means, for conditioning or altering the flow of at least one of the separate streams in a manner affording an accelerated mixing of the hot and cold streams entering the inlet portion of the nozzle means.

A further object of this invention is to provide a plural gas stream jet propulsion apparatus of the type hereinbefore referred to with an improved control effective to increase the power output of the prime mover and to decrease the power requirements of the compressing means driven thereby under conditions normally effective to decrease and increase said power output and said power requirements, respectively. This result is accomplished by means effective to increase the jet area as the altitude decreases, thereby reducing the back pressure on the turbine element as well as the pressure in the relatively cold stream.

The invention accordingly consists of the various features of construction, combinations of elements and arrangements of parts as is more fully set forth in the appended claims and in the description, reference being had to the accompanying drawings, in which:

Fig. 1 schematically illustrates a longitudinal section through a symmetrical jet propulsion unit embodying the invention; and

Fig. 2 is an enlarged transverse section taken on line II—II of Fig. 1.

Referring to the drawing, it is seen that the invention may be embodied in a unit comprising an axial flow compressor 1 having a low pressure section 2 and a high pressure section 3, an axial flow turbine 4 axially spaced from and drivingly connected with the adjacent end of the compressor 1 by means of a shaft 6, an inner shell 7 surrounding the shaft 6, an intermediate shell 8 surrounding and forming with the active blade carrying portion of the high pressure compressor section 3, with the inner shell 7 and with the active blade carrying portion of the turbine 4 an inner passage 9 including a plurality of fuel distributing nozzles 11 disposed therein between the discharge end of the compressor section 3 and the inlet to the turbine 4, and an outer shell 12 surrounding and forming with the low pressure compressor section 2 and with the intermediate shell 8 an outer passage 13 receiving a portion of the air discharged from the low pressure compressor section 2; the remainder of the air compressed in the low pressure section 2 entering the high pressure compressor section 3 from which it is discharged into the inner passage 9.

The compressor end of the outer shell 12 extends forwardly beyond the low pressure compressor section 2 and forms with a coaxially extending cone-shaped casing 14 enclosing the adjacent shaft portion of the compressor 1 a forwardly facing inlet passage 16 through which air enters the active blade carrying portion of the low pressure compressor section 2. The turbine end of the outer shell 12 has a coaxially extending portion 17 telescopically mounted thereon for axial adjustment by means of a plurality of circumferentially spaced series of balls 18 disposed in axially extending ball retaining races 19 provided on the adjacent end portion of the shell 12 as shown; said axial adjustment being effected by turning a coaxially extending shaft 21 having a journal portion 22 rotatably mounted in a bearing block 23 secured to the outer shell 12 and having a threaded portion 24 which extends through a coaxial internally threaded bore provided in a block or the like 26 secured to the portion 17. Axial movement of the shaft 21 is prevented by means of a collar 27 and a pinion 28 which are secured to the shaft in engagement with opposite sides of the bearing block 23. The pinion 28, which provides means for effecting a rotation of the shaft 21 as desired, may be turned by any suitable remotely controlled gear means (not shown). Axial movement of the portion 17 in the rearward direction may be limited in any suitable manner such as by means of a nut 29 on the shaft 21.

The portion 17 forms with a coaxially extending cone-shaped casing 31 enclosing the adjacent shaft portion of the turbine 4, a rearwardly directed jet forming nozzle passage 32, the length and cross sectional area of which can be readily varied by effecting an axial adjustment of the portion 17. In operation, air entering the forwardly facing inlet passage 16 is compressed to a predetermined degree in the low pressure compressor section 2 and is then divided by means of the intermediate shell 8 into two separate streams one of which, the inner stream in this case, is first further compressed to a predetermined higher degree in the high pressure compressor section 3, then highly heated in any suitable manner, for example, by burning fuel therein which may be introduced through nozzles or burners as shown in Fig. 1, and then expanded to a predetermined degree in the turbine 4 and the other of which, the outer stream in this case, is conducted by means of the outer passage 13 directly to the nozzle passage 32 in which the outer relatively cool stream mixes with the hot stream issuing from the turbine 4; the mixture then expanding in the passage 32 to produce a rearwardly directed propelling jet or blast having the velocity desired for a given wake efficiency, that is, the efficiency of the jet or blast as a propelling means.

In order to obtain the best results, that is, the highest overall propulsion efficiency for given jet and vehicle-translation velocities, it is essential that the separate streams be confiningly combined to produce a mixture having a substantially uniform temperature before confiningly expanding the mixture to the velocity desired for a given wake efficiency. In other words, the separate streams should, upon entering the passage 32, become mixed sufficiently while moving a relatively short distance axially thereof to produce a resultant stream having an approximately uniform temperature before the resultant stream expands materially, that is, before the velocity of the resultant stream materially increases, which effects a corresponding decrease in its temperature and pressure. In this connection, turbulent flow exists in both the inner and outer passages and the turbulence of the inner and outer streams of fluid entering the passage 32 will, if adequate, quickly effect a degree of mixing sufficient for the confined expansion of the fluid therein to the velocity desired for a given wake efficiency, that is, sufficient mixing takes place to permit a confined expansion of the mixture to a velocity such that the momentum of the propelling blast of mixture issuing from the passage 32 is greater than the sum of the momenta which would be attained by said streams if separately expanded from the same pressure; said pressure being considered equal to that of the resulting mixture before expansion since there is no appreciable loss in pressure due to mixing and since the pressures of the separate and mixed streams decrease substantially the same amount in flowing the same distance.

And if the separate streams entering the passage 32 are in a condition of flow such that their turbulence determines the degree and rapidity of mixing therein, it may in some instances be desirable, in order to change the turbulence in one or both of said streams to thereby alter the degree and rapidity of mixing, to provide the discharge end portions of the separate passages with any suitable means for increasing the turbulence therein, such for example, as the vanes 33 shown in the outer passage 13 of Fig. 1. The inclusion of means for increasing the turbulence in said passages results in an increased pressure drop therein and it is therefore preferable, in the interest of minimizing energy losses, to so dimension the passage 32 that the use of such means is unnecessary as for instance, by making the inlet end of portion 17 and the inlet end of casing 31 substantially parallel for a material distance in the direction of fluid flow therethrough, as shown, in order to provide a coaxial rearwardly facing expanding nozzle structure embodying in proximate relation to the exhaust end of the turbine 4 and to the discharge end of the passage 13 a fluid receiving and mixing end portion which is of material length in the direction of fluid flow therethrough and is of substantially uniform cross section throughout its said length. However, it is entirely immaterial whether the aforementioned mixing of the separate gas streams before expansion thereof is produced by conditions of turbulence or by any other conditions of flow as the primary consideration in this connection is to rapidly effect the desired degree of mixing with minimum energy loss, i. e., the condition or nature of flow of one or both streams should be such as to effect an efficient accelerated mixing of the streams combined within the inlet portion of the expanding nozzle structure. The controlling factors comprising degree of compression effected in the compressor sections 2 and 3, the degree of heating effected in the passage 9, the degree of expansion and the heat drop effected in the turbine 4, the dimensions of passages 9, 13 and 16, and the velocity of the streams issuing from the turbine 4 and from the passage 13 can be readily determined by anyone skilled in the art knowing the altitude at which the unit is to be operated, the translational velocity to be attained by the unit and the desired wake efficiency.

Having determined the hereinabove specified factors, it then remains to determine the degree and the rapidity of mixing which can be effected by confiningly combining the separate streams and whether additional means must be provided for increasing the turbulence in one or both of said streams in order to obtain a mixture having an approximately uniform temperature before expansion thereof in a nozzle passage of practical dimensions. The increase in momentum effected by mixing and expanding two streams under ideal conditions is proportional to the ratio

$$\frac{\sqrt{(K+1)(K+C)}}{K+\sqrt{C}}$$

which is derived from formula based on ideal gas laws expressing the momentum attained by mixing two gas streams of different temperature and expanding the mixture to obtain a desired velocity and expressing the sum of the momenta attained by separately expanding said streams to the same degree and in which K equals the quotient obtained by dividing the cold gas mass flow by the hot gas mass flow and C equals the quotient obtained by dividing the absolute temperature of hot gas stream by the absolute temperature of the cold gas stream. Said formula can be developed by anyone skilled in this art, and a further description in this connection is deemed unnecessary for a complete understanding of the invention, it being sufficient to point out that said formula clearly establishes that the momentum attained by the mixture is always greater than the sum of the momenta attained by separately expanding said streams and that therefore the hereinabove designated ratio will always be greater than one if the temperatures of the gas streams are unequal.

However, it thus far has been impossible to develop a mathematical solution of the problem of determining the degree and the sufficiency of the mixing effected by confiningly combining separate streams having materially different temperatures, and it has therefore been necessary to set up apparatus assimilating actual conditions and measure the degree of mixing effected therein, which may be done by taking temperature readings throughout the portion of the stream in which mixing is to be effected. If sufficient mixing is obtained, the temperature should be approximately uniform throughout said portion, and it should therefore be obvious that the temperature readings will indicate the degree of mixing effected.

The temperature of the air entering the inlet passage 16 increases as the altitude of the unit decreases which in turn increases the power requirements of the compressor and thereby reduces the overall efficiency of the unit. However, the portion 17 can be axially adjusted to increase the jet area (the position shown in Fig. 1 is that for effecting the maximum area), thereby reducing the nozzle back pressure which in turn reduces the power requirements of the compressor and increases the effective power output of the turbine. When the unit is operating at the altitude for which it is designed, the portion 17 should be positioned to effect a reduction in the jet area, and as the altitude decreases, the position of the member 17 should be adjusted to effect a proportionate increase in the jet area; said adjustment being accomplished by turning the shaft 21 which may be accomplished by any means suitable to effect the desired result. This control operates to simultaneously vary the back pressure on both the inner and outer passages, and it is therefore unnecessary to reduce the pressure in the outer path as much as would be necessary if no control of the inner passage could be effected.

In a dual stream jet system, that is, one in which hot and cold streams are separately expanded to produce separate propelling jets, it is essential that unequal pressures and unequal temperatures exist in said streams before expansion in order to obtain equal low jet velocities and equal wake efficiencies in both jets. In such systems, the velocity of the cold jet is generally considered as limited by the sound velocity and by the take-off characteristics of the unit. However, the sound velocity increases with temperature, and therefore the hereinbefore described mixing of said streams before expansion thereof results in a higher jet temperature and therefore a higher jet velocity without a decrease in efficiency. In addition, the take-off characteristics will be materially improved by the hereinbefore described control.

The invention is of general application to jet propulsion units embodying a plurality of separate streams having materially different temperatures irrespective of the number, grouping and arrangement of said streams, and it should therefore be understood that it is not desired to limit the invention to the exact details of construction or to the exact mode of operation herein shown and described, as various modifications within the scope of the appended claims may occur to persons skilled in the art.

It is claimed and desired to secure by Letters Patent:

1. A jet propulsion unit comprising in coaxial relation fluid compressing means having a forwardly facing inlet and high and low pressure fluid discharge portions, a turbine drivingly connected with said compressing means, means forming a first passage connecting said high pressure discharge portion with the inlet end of said turbine and a second passage connected with said low pressure discharge portion and terminating adjacent the exhaust end of said turbine, means for increasing the temperature of the high pressure fluid flowing through said first passage, and means forming a coaxial nozzle structure which extends rearward from the exhaust and discharge ends of said turbine and second passage, said nozzle structure including an expanding portion immediately preceded by an inlet end portion having a substantially uniform cross-sectional area for an appreciable distance measured in the direction of gas flow therethrough wherein the fluids leaving said turbine and second passage become sufficiently mixed to attain an approximately uniform temperature before entering said expanding portion.

2. In combination in a jet propulsion apparatus embodying compressing, heating, turbine and an expanding nozzle means correlated to produce and combine in the inlet end of said nozzle means separate gas streams including a hot gas stream for operating the turbine and a cold gas stream, means other than said compressing, heating and turbine means for contacting and conditioning at least one of said separate streams to effect an accelerated mixing of the hot and cold gas streams on entering the inlet end of said nozzle means.

3. In combination in a jet propulsion apparatus embodying compressing, heating, turbine and an expanding nozzle means correlated to produce and combine in the inlet portion of said nozzle means separate gas streams including a hot gas stream for operating the turbine and a cold gas stream, means other than said compressing, heating and turbine means disposed in upstream relation with respect to the inlet end of said nozzle means for contacting and conditioning at least one of said streams to effect an accelerated mixing of the separate hot and cold gas streams on entering the inlet end of said nozzle means.

4. A jet propulsion apparatus comprising in combination an expanding nozzle structure, an elastic fluid compressing means, a turbine drivingly connected with said compressing means, a first means connecting the discharge of said compressing means with the inlet to said turbine and forming therewith a first conductor discharging into the inlet end portion of said nozzle means,

a second means connected with the discharge of said compressing means and forming a second conductor also discharging into said inlet end portion of the nozzle means, means in addition to said compressing means for increasing the temperature of fluid flowing through said first conductor prior to its passage through said turbine, and additional means associated with at least one of said conductors for conditioning the stream of fluid flowing therethrough to effect an accelerated mixing of the separate streams of fluid on entering said inlet end portion of the nozzle means.

5. A jet propulsion apparatus comprising in combination an expanding nozzle structure, an elastic fluid compressing means, a turbine drivingly connected with said compressing means, means connecting the discharge of said compressing means with the inlet to said turbine and forming therewith a first conductor discharging into the inlet end portion of said nozzle means, additional means connected with the discharge of said compressing means and forming a second conductor also discharging into said inlet end portion of the nozzle means, means in addition to said compressing means for increasing the temperature of fluid flowing through said first conductor prior to its passage through said turbine, and means other than said compressing, heating and turbine means disposed in at least one of said conductors for contacting and conditioning the stream of fluid flowing therethrough to effect an accelerated mixing of the streams of fluid discharging from said first and second conductors into said inlet end portion of the nozzle means.

6. In combination in a jet propulsion apparatus embodying compressing, heating, and turbine means correlated to produce separate gas streams including a hot gas stream for operating said turbine and a cold gas stream, a nozzle structure combiningly receiving said hot and cold gas streams, said nozzle structure including an expanding portion immediately preceded by an inlet end portion of substantially uniform cross-sectional area for a distance measured in the direction of gas flow therethrough such that the hot and cold gas streams entering said inlet end portion become sufficiently mixed therein to attain an approximately uniform temperature before entering said expanding portion.

7. In combination in a jet propulsion apparatus embodying compressing, heating, and turbine means correlated to produce separate gas streams including a hot gas stream for operating said turbine and a cold gas stream, a coaxial expanding nozzle structure combiningly receiving said hot and cold gas streams and including an inlet end portion which is of substantially uniform cross-sectional area for a considerable distance measured in the direction of gas flow therethrough, and means other than said compressing, heating and turbine means for contacting and conditioning at least one of said streams to effect an accelerated mixing of the separate hot and cold gas streams on entering the inlet end portion of said nozzle means.

8. In combination in a jet propulsion apparatus embodying compressing, heating, and turbine means correlated to produce separate gas streams including a hot gas stream for operating said turbine and a cold gas stream, a coaxial expanding nozzle structure combiningly receiving said hot and cold gas streams and including an inlet end portion of substantially uniform cross-sectional area for a considerable distance measured in the direction of gas flow therethrough, and means disposed in immediate upstream relation with respect to the inlet end of said nozzle structure for contacting and conditioning at least one of said streams to effect an accelerated mixing of the hot and cold gas streams on entering the inlet end portion of said nozzle structure.

9. In combination in a jet propulsion apparatus embodying compressing, heating, and turbine means correlated to produce separate gas streams in a state of relative turbulence and including a hot gas stream for operating said turbine means and a cold gas stream, a nozzle structure combiningly receiving said hot and cold gas streams, said nozzle structure including an expanding portion immediately preceded by an inlet end portion having a substantially uniform cross-sectional area for a sufficient distance measured in the direction of gas flow therethrough such that the hot and cold gas streams entering said inlet end portion rapidly mix therein and attain an approximately uniform temperature before entering said expanding portion.

10. A jet propulsion apparatus comprising compressing, heating, and turbine means combined and correlated to produce separate gas streams including a hot gas stream for operating said turbine means and a cold gas stream, and a nozzle structure including an expanding portion immediately preceded by an inlet end portion combiningly receiving said hot and cold gas streams, said combined and correlated means including at least one portion thereof constructed and arranged to alter the flow of said separate streams so that the separate gas streams enter the inlet end portion of said nozzle structure in a state of flow such that the separate streams mix therein with sufficient rapidity to attain an approximately uniform temperature before entering said expanding portion of the nozzle structure.

11. A jet propulsion apparatus comprising compressing, heating, and turbine means combined and correlated to produce separate gas streams including a hot gas stream for operating said turbine means and a cold gas stream, and a nozzle structure including an expanding portion immediately preceded by an inlet end portion combiningly receiving said hot and cold gas streams, said combined and correlated means including at least one portion thereof constructed and arranged to alter the flow of the separate gas streams entering the inlet end portion of said nozzle structure in a manner such that the separate streams undergo an accelerated mixing therein and attain an approximately uniform temperature before entering said expanding portion of the nozzle structure.

JOHN ALGOT JOHNSON.

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