United States Patent [19]

Melenric

[11] **3,823,554**

[45] **July 16, 1974**

[54] **HIGH SPEED VALVELESS RESONANT PULSE JET ENGINE**

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[52] **U.S. Cl.** **60/249,** 60/39.77, 60/39.49

[51] **Int. Cl.** **F02k 7/04**

[58] **Field of Search** 60/249, 247, 248, 39.76, 60/39.77, 39.8, 39.71

[56] **References Cited**

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3,517,510	6/1970	Melenric	60/249

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Assistant Examiner—Warren Olsen
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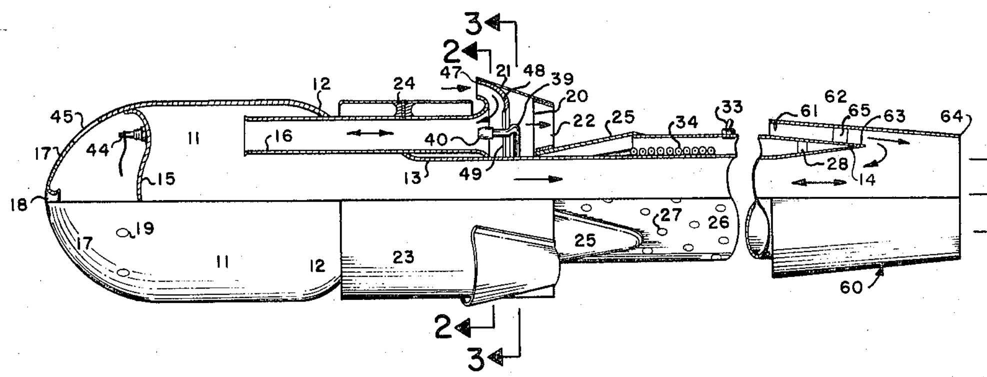
[57] **ABSTRACT**

A valveless resonent pulse jet engine particularly adapted to power target vehicles or pilotless aircraft at speeds of Mach 0.5 to Mach 1. This invention is an improved high-speed adaptation of my U.S. Pat. No. 3,517,510. The device of this invention continues to utilize a substantially cylindrical combustion chamber, a reduction cone and an exhaust tube, a multiplicity of reverse flow air fuel inlet tubes projecting through the reduction cone into the combustion chamber. Annular reverse flow vanes surround the bell mouth of the air inlet tubes thereby increasing static pressure at the air inlet as forward speed of the vehicle increases. An exhaust tube diffuser is employed in a similar fashion to assist the pulsating reverse flow of ambient air into the exhaust tube to increase thrust at high forward speeds.

10 Claims, 4 Drawing Figures



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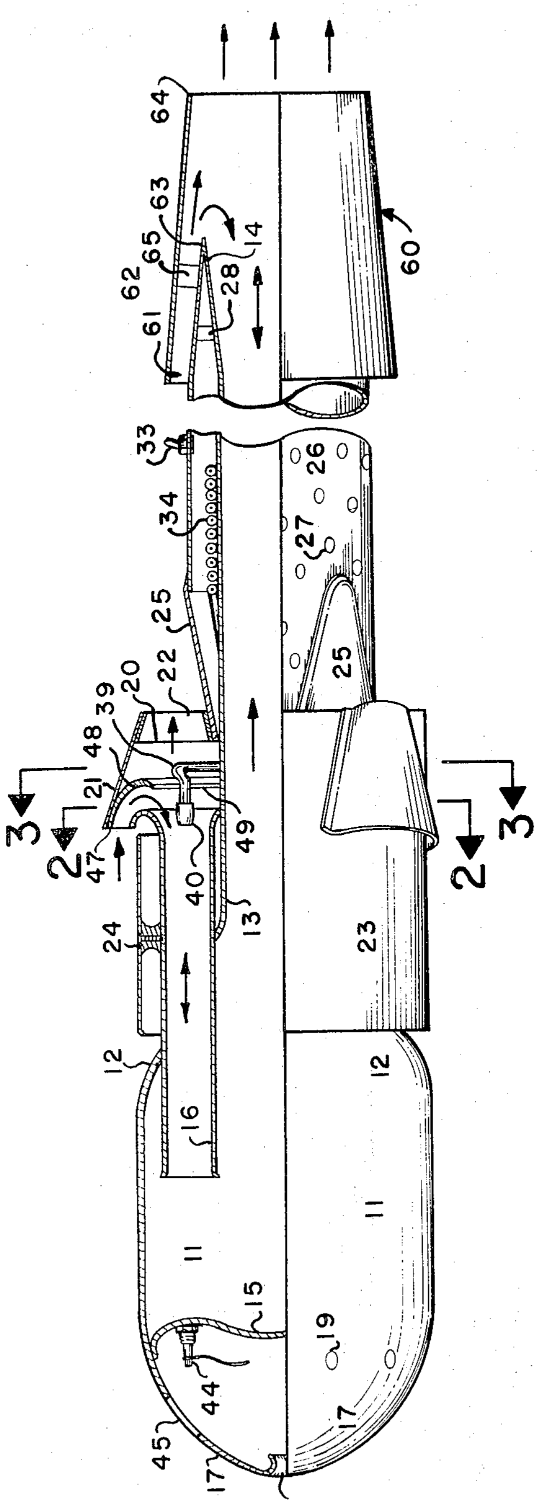

FIG. 1

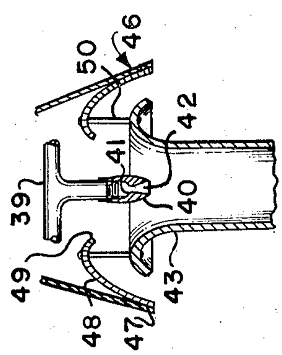

FIG. 4

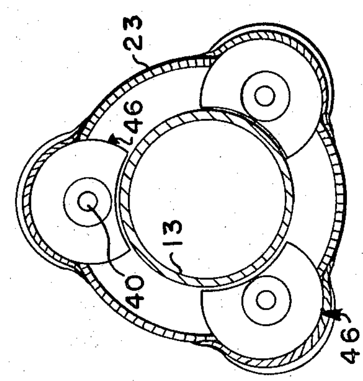

FIG. 3

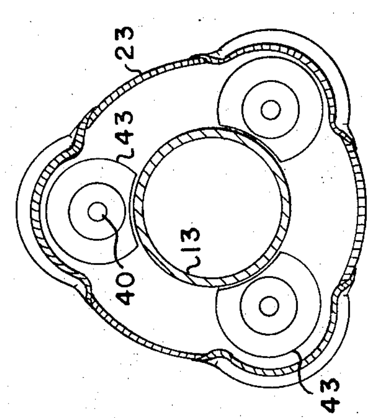

FIG. 2

HIGH SPEED VALVELESS RESONANT PULSE JET ENGINE

CROSS REFERENCE TO RELATED APPLICATION

The device of this invention is directly related to applicant's U.S. Pat. No. 3,517,510. Many of the construction features of the device of this invention are identical with the above referred to patent. The device of this invention is an improved high-speed adaptation of the previously patented device. Experimental results have shown that the previously patented device is highly satisfactory for low speed flight or stationary use as a space or orchard heat. At speeds from Mach 0.5 to Mach 1 flame moves aft in the exhaust tube and thrust is decreased and flame-out can occur. To insure and obtain satisfactory operating characteristics from Mach 0.5 to Mach 1 annular reverse flow vane has been constructed to surround the bell mouth of the intake tube to increase static pressure and inject air into the tube. To insure reverse flow into the exhaust nozzle a truncated conical exhaust tube diffuser is constructed around the exhaust nozzle to insure proper reverse flow of air or increase static pressure at the exhaust nozzle retaining the pulsating flame in the appropriate operating areas of the device.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains to a resonant valveless pulse jet engine designed for high-speed operation. Previously existing pulse jets generally lost thrust and operating characteristics deteriorated above Mach 0.5. The device of this invention is particularly designed with a view to retaining optimum thrust and operating characteristics at speeds above Mach 0.5. This is accomplished through the use of the annular reverse flow vanes and the exhaust tube diffuser.

DESCRIPTION OF THE PRIOR ART

The closest related prior art is your applicant's U.S. Pat. No. 3,517,510 issued June 30, 1970. For a general illustration of the state of the art, reference is made to Project Squid, Department of the Navy, Research Project, and Technical Memorandum No. PR.—4 concerning the background and development of the German V—1 Ing. Guenther Dietrich translated by A. Kahane, June 30, 1948, Princeton University, and Technical Memorandum No. CAL—27 by Joseph G. Logan, Jr., May, 1949, by Cornell Aeronautical Laboratories. The examples of valveless pulse jets are Schuberts and SNECMA.

SUMMARY OF THE INVENTION

The device of this invention basically incorporates the disclosure of my U.S. Pat. No. 3,517,510 with the addition of substantially circular annular reverse flow vane encircling the bell mouth of each fuel air inlet tube. This annular reverse flow vane is of substantially greater diameter than the bell mouth of the inlet tube. The vane collects air as the engine of this device obtains forward momentum and through reverse flow lip inject and increases static pressure at the air fuel inlet tubes. The second improvement of this invention pertains to the exhaust tube diffuser which is constructed on the engine at the nozzle end of the exhaust tube. Improvement in this area of the device comprises a substantially elongated truncated cone exhaust tube diffuser inlet or the base of the conical-like strucutre projects forward and catches and forces air into the exhaust nozzle as forward speed of the engine increases. Experiments conducted in a plenum chamber with previous device conclusively establishes the fact that at high speeds or at increased pressures at the air fuel inlet tubes causes the flame to move to the nozzle end of the exhaust tube. The exhaust tube diffuser of the invention of this device increases pressure or reverse flow into exhaust tube nozzle moving the flame back into the engine to the desired operating area and restores thrust of the engine. The diameter of the exhaust tube diffuser is directly proportional to the design speed of the engine. The higher the design speed, the larger the required diameter of the exhaust tube diffuser.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevation view partially in cross section of the engine of this invention.

FIG. **2** is a cross sectional view of the device taken substantially on line **2—2** of FIG. **1** looking in the direction of the arrows. This view discloses primarily the bell mouth of the air fuel inlet tubes.

FIG. **3** is a sectional view of FIG. **1** taken substantially on line **3—3** looking in the direction of the arrows disclosing primarily the outer surface of annular reverse flow vanes.

FIG. **4** is a fragmented sectional view of the bell mouth nozzle of the air-fuel inlet tube surrounded by a fragmented sectional view of the annular reverse flow vanes and brackets.

DESCRIPTION OF THE PREFERRED EMBODIMENT

For a description of the preferred embodiment, its method of construction, and operation, reference is made to the attached views and the following detailed description wherein identical reference characters refer to identical or equivalent components throughout the several views and the following detailed description.

The device of this invention may be constructed from various metals or alloys; however, the preferred embodiment was constructed from 321 or 347 type stainless steel AMS spec 5510, 5512 or 5570. Any of the number of acceptable methods could be employed for securing the components in a unitary structure; however, in the preferred embodiment, heliarc welding was primarily used in the construction. For a description of the construction of the device of the invention, one might well refer to my previous U.S Pat. No. 3,517,510. Many of the components and methods of construction are identical. Referring to FIG. **1**, the device is constructed around a substantially cylindrical combustion chamber **11**. Aft of the combustion chamber **11** is constructed or secured the combustion chamber reduction cone **12** to which is attached the elongated exhaust tube **13** which terminates at its aft end in the exhaust tube nozzle **14.** Secured to the forward end of the combustion chamber **11** is combustion chamber forward wall **15.** This wall is slightly arched to prevent fatigue of the metal; however, the desierd flow characteristic dictates a forward wall **15** constructed at substantially right angles to the axis of the exhaust tube **13.**

A multiplicity of air and fuel inlet tubes **16** are equiangularly positioned in reduction cone **12** and project into the cylindrical combustion chamber **11.** These air and fuel inlet tubes **16** are constructed on an axis parallel to the axis of combustion chamber **11** and the exhaust tube **13.** Heliarc welding is a statisfactory method of securing the tubes **16** to reduction cone **12.** Secured to the forward end of combustion chamber **11** is nose cone **17** into which is constructed with a cooling vent **18** and air exit vents **19** to assist in dissipating heat from the combustion chamber forward walls **15.** The principal diagonal structure member in the midsection of the engine is vertical support plate **20.** This plate **20** is welded to exhaust tube **13.** Welded to the support plate **20** are the various fairing components of the device and air scoops **21** as well as air scoop support rings **22.** Projecting forward from this vertical support plate **20** is outer circular fairing **23** which surrounds and may be secured to air and fuel inlet tubes **16** by connecting brackets **24.**

The secondary exhaust deflection plates **25** with slightly dish configurations are secured to or constructed in exhaust tube fairing **26**; air inlet holes **27** are constructed in exhaust tube fairing **26** to assist in the dissipating of heat from the space between fairing **26** and tube **13.** To reinforce these two structures securing brackets **28** might well be employed for increased structural rigidity.

It is visualized that fueling for the device of this invention might be accomplished with structures as previously described in my U.S. Pat. No. 3,517,510. However, in view of the fact that the device of this invention is primarily designed for continuous operation at maximum thrust and high speeds, a somewhat simplified fueling method may be employed for providing gaseous or liquid fuels to power the device such as butane, propane, hydrogen, or a mixture of fuels. These liquid fuels would preferably be fed through a heat exchange fuel line **33** which encircles the exhaust tube **13** in a series of coils comprising a heat exchange **34.** Liquified gaseous fuel passes through fuel nozzle feed line **39** into a supersonic fuel nozzle **40.** These nozzles **40** are well known to the art and more completely described in my previous patent. For a brief description of this nozzle, reference is made to FIG. **4.** Nozzle **40** has a minimum section **41** which projects into a nozzle flare **42.** These nozzles **40,** for optimum operation, must be positioned exactly at the beginning of the flare of the inlet tube bell mouth **43.** To initiate operation of the device of this invention, gaseous fuel would preferably be injected into the device. After combustion is initiated by sparking plug **44** positioned in the combustion chamber forward wall **15** for maximum thrust, the device should be fueled with liquified gaseous fuel. Nose cone **17** is provided with spark plug access cover **45** and sparking plug **44** may be fired by a conventional vibrator ignition system. No timing of the spark is required and after initiation of combustion the ignition may be turned off in that the combustion is self-sustained.

For a detailed description of the improvements incorporated in the device which are elements in combination comprising the invention of this application, your attention is particularly invited to FIGS. **1, 3** and **4.** The annular reverse flow vanes **46** surround inlet tube bell mouth **43** in the manner illustrated in FIGS. **1, 3,** and **4.** This annular reverse flow vanes **46** are arcuate conical-like structures with their largest diameter comprising the forward intake section **47** secured to the forward edge of air scoop **21.** These annular reverse flow vanes **46** are constructed with an arcuate reduction cone **48** projecting into a reverse flow lip **49** which surrounds inlet tube bell mouth **43** and is secured to the bell mouth **43** by means of reverse flow vane brackets **50.** These various components are perhaps best illustrated in FIG. **4.** Examination of this structure of FIG. **4** in a measure illustrates the manner in which these annular reverse flow vanes **46** catch air and project it into the inlet tube bell mouths **43.**

Another feature previously mentioned contributing substantially to the high speed performance of the device of this invention is the exhaust tube diffuser **60** secured to the exhaust tube nozzle **14.** This exhaust tube diffuser **60** is a truncated conical structure, the base projecting forward around the exhaust tube **13** nozzle **14.** The largest diameter in the forward edge comprises diffuser inlet **61.** The channel between exhaust tube fairing **26** and exhaust tube diffuser **60** comprises a diffuser flow channel **62.** The area of reverse flow into the nozzle **14** is designated as the diffuser intake **63.** The diffuser **60** terminates at its aft end in diffuser exhaust cone **64.** The device is made integral with exhaust tube nozzle **14** and exhaust tube fairing **26** by means of diffuser brackets **65.**

Reference is made to my U.S. Pat. No. 3,517,510 for the relative diameters of the various components of the preferred embodiment, as well as for a description of the pulsating wave characteristics of this valveless resonant pulse-jet.

OPERATION OF THE DEVICE

When the device is fueled through nozzles **40,** fuel and air are induced through the air and fuel inlet tubes **16** into combustion chamber **11.** Ignition is initiated by sparking plug **44.** Ignition causes a shock or thrust wave to move aft in the exhaust tube **13.** The subsequent drop in pressure in the combustion chamber **11** causes induction of a new air and fuel charge through air and fuel inlet tubes **16.** For low speed operation of the device of my previous invention, air scoops **21** reduced the static rate of flow of air passed the inlet tube bell mouth **43** adequately to provide air for operation of the device at stationary or moderate forward speed. At speeds above Mach 0.5 the old structure is not satisfactory. Accordingly, annular reverse flow vanes **46** surrounding bell mouth **43** and air inlet tubes **16** are required. These annular reverse flow vanes **46** will, at high forward speeds, catch and reverse the flow of air passed the intake end of the inlet tubes **16** and in effect, inject air into bell mouth **43.** This characteristic of the various components of the annular reverse flow vanes **46** substantially improve the air and fuel intake characteristics at speeds above Mach **.5.**

A secondary component, however, is necessary to avoid combustion moving aft in the exhaust tube **13.** This comprises exhaust tube diffuser **60.** This diffuser **60** somewhat in the manner of annular reverse flow vanes **46** grasps and induces air adjacent the exit of exhaust tube nozzle **14.** The rate of flow is decreased through diffuser flow channel **62** increasing static pressure. This increased static pressure permits air to reverse flow into the exhaust nozzle **14** restoring pressure at the nozzle **14** moving the flame forward in the exhaust tube **13** restoring thrust. The combination of the structure of the annular reverse flow vanes **46** and the exhaust tube diffuser **60** in combination with the overall device are the principal features of this invention.

By emphasizing the structural features of this improved device, I do not intend to specifically limit my claims to the exact structure described. What is desired to be claimed is all devices incorporating equivalent structures not departing from the scope of the appended claims or their equivalents.

I claim:

1. A self starting valveless pulse jet engine comprising:

a. a substantially cylindrical combustion chamber of circular cross section,

b. an elongated substantially cylindrical exhaust tube of circular cross section projecting aft from said combustion chamber constructed and arranged on a common axis with the axis of said combustion chamber,

c. a reduction cone intermediate said combustion chamber and said exhasut tube,

d. a multiplicity of straight air and fuel inlet tubes constructed in a single axis configuration mounted in said reduction cone projecting into said combustion chamber, the construction and arrangement of the combustion chamber, exhaust tube, and air fuel intake tube combination places the axis of each said element substantially parallel with the axis of each other said element,

e. an inlet tube bell mouth constructed in the respective intake ends of said air and fuel inlet tubes,

f. a multiplicity of annular reverse flow vanes spaced from and substantially encircling said inlet tube bell mouth, said annular reverse flow vanes having an arcuate configuration adapted to entrap and deflect air into said inlet tube bell mouths,

g. fuel supply means operably associated with said combustion chamber and,

h. ignition means operably associated with said combustion chamber.

2. The invention of claim **1** wherein said annular reverse flow vanes comprise:

a. an intake section projecting forward said intake section being flared and of substantially greater diameter than said fuel and air inlet tubes,

b. an arcuate reduction cone constructed in said annular reverse flow vanes projecting aft of said intake section, said arcuate reduction cone projecting aft at a progressively reduced diameter, said reverse flow vanes terminating in,

c. a reverse flow lip projecting forward substantially in the direction of the inlet tube bell mouth.

3. The invention of claim **1** including:

a. an exhaust tube nozzle secured to the aft end of said exhaust tube, and

b. an exhaust tube diffuser secured to and encircling said exhaust tube nozzle, said exhaust tube diffuser constructed and arranged to reduce the rate of flow of ambiant air adjacent said exhaust tube nozzle.

4. The invention of claim **3** wherein said exhaust tube diffuser comprises:

a. a diffuser inlet of substantially greater diameter than the diameter of said exhaust tube,

b. a diffuser flow channel projecting aft at a progressively reduced diameter, and said exhaust tube diffuser terminating in

c. a diffuser exhaust cone having a diameter less than the diameter of said diffuser inlet.

5. The invention of claim **1** wherein said combustion chamber includes a substantially flat forward wall normal to the axis of said exhaust tube.

6. The invention of claim **1** wherein the said air and fuel inlet tubes are substantially equiangular positioned in said combustion chamber.

7. The invention of claim **1** wherein the fuel supply means includes a convergent-divergent supersonic fuel nozzle positioned in the inlet end of said air and fuel inlet tubes.

8. The invention of claim **1** including a fuel nozzle positioned in substantially the center of said bellmouth at its juncture with said air and fuel inlet tube.

9. The invention of claim **5** wherein the said ignition means includes a spark plug positioned in the said forward wall at a position substantially in prolongation of the axis of one of the said air and fuel inlet tubes.

10. The invention of claim **1** wherein the dimensional proportions are relatively:

a. the diameter of the combustion chamber is substantially twice the diameter of the exhaust tube,

b. the combustion chamber, combustion chamber reduction cone, and exhaust tube combination is substantially fifteen (15) exhaust tube diameters in length,

c. the length of each of the air and fuel inlet tubes is one-fourth (¼) the length of the combustion chamber, combustion chamber reduction cone, and the exhaust tube combination, and

d. the total cross-sectional intake area of the said air and fuel inlet tubes is one-third of the cross-sectional area of the said exhaust tube.

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