Valveless Pulsejet Patent Granted to Pulse Jet Corp in 1967

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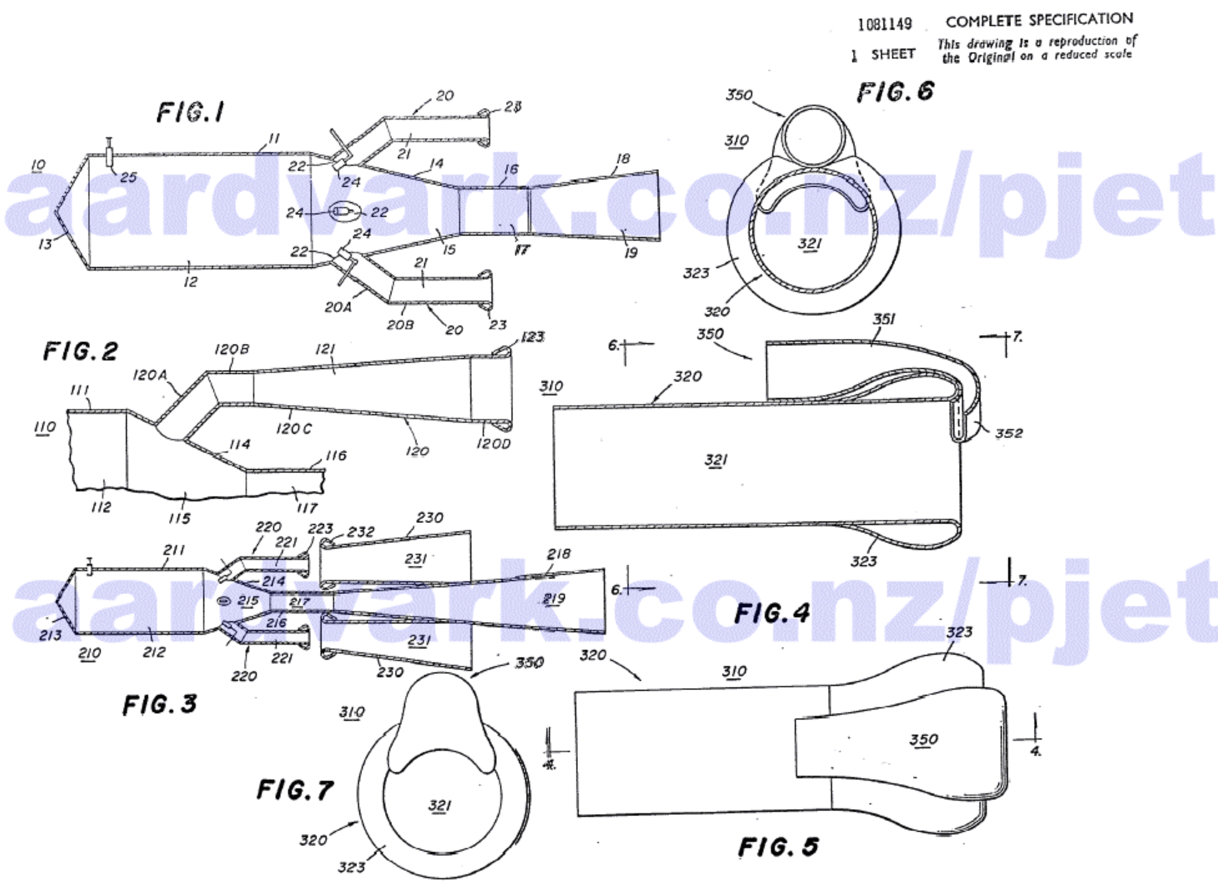

PATENT SPECIFICATION 1,08

DRAWINGS ATTACHED.

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COMPLETE SPECIFICATION.

Pulse Jet Engine.

We, PULSE JET CORPORATON, a Corporation organised under the laws of the State of Delaware, United States of America, of 105 West Adams Street, City of Chicago, State of Illinois, United States of America, do hereby declare the invention, for which we pray that a patent may beg ranted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The present invention relates to pulse-jet engines of the valveless type, and more particularly to such engines of improved construction and arrangement.

It is a general aspect of the invention to provide a pulse-jet engine of the valveless type that is of compact and economical construction and having a greater thrust per unit weight and per unit volume than prior engines of this type.

Pulse-jet engines of the character of those herein disclosed are particularly advantageous for incorporation into an airplane as an auxiliary engine. A conventional airplane having a main engine of the piston type operatively connected to a propeller may also have at least one auxiliary engine of the pulse-jet type, together with an arrangement for placing the auxiliary engine into operation in the event of failure of the main engine.

An advantage of the present invention is in providing a pulse-jet engine of improved and simplified construction and arrangement that is exceedingly compact and lightweight with respect to the forward thrust delivered thereby and relative to conventional engines, whereby the improved engine is ideally suited as an auxiliary engine in an airplane that is normally operated by a propeller driven by a conventional engine of the piston type.

Another advantage of the invention is that the pulse-jet engine, or direct-reaction motor, is subject to intermittent combustion, provided with no moving parts, and is generally of elongated tubular construction.

In particular, the present invention provides a pulse-jet engine comprising an elongated longitudinally extending tubular first section defining therein a primary combustion chamber, a cap connected to the front end of the said first section and closing the adjacent front end of said primary combustion chamber to the atmosphere, an elongated longitudinally extending and rearwardly converging tubular second section defining therein a secondary combustion chamber, the rear end of said first section being connected to the front end of said second section with the rear end of said primary combustion chamber opening into the adjacent front end of said secondary combustion chamber, an elongated longitudinally extending tubular third section defining an exhaust passage therethrough, the rear end of said second section being connected to the front end of said third section with the rear end of said secondary combustion chamber opening into the front end of said exhaust passage, the rear end of said third section being open, whereby the rear end of said exhaust passage constitutes an exhaust gas nozzle communicating with the atmosphere, an elongated longitudinally extending tubular fourth section defining an inlet passage therethrough, one end of said fourth section being connected to the front portion of said second section with the adjacent front end of said inlet passage opening into the front portion of said secondary combustion chamber, the other end of said fourth section being open, whereby the adjacent other end of said inlet passage constitutes 1,149 c IR r_ PM V, - 1,081,149 an air inlet nozzle communicating with the atmosphere, means for injecting fuel into said primary combustion chamber, and means for igniting a combustible mixture of fuel and air in said primary combustion chamber.

In the accompanying drawings:

Figure 1 is a longitudinal sectional view of a pulse-jet engine embodying the present invention.

Figure 2 is an enlarged fragmentary longitudinal sectional view of a modified form of the pulse-jet engine, as shown in Figure 1;

Figure 3 is a reduced longitudinal sectional view of another modified form of the pulse-jet engine, as shown in Figure 1;

Figure 4 is an enlarged longitudinal sectional view of a portion of a further modified form of the pulse-jet engine, as shown in Figure 1, this view being taken in the direction of the arrows, along the line 4-4 in Figure 5;

Figure 5 is an enlarged plan view of the portion of the pulse-jet engine, as shown in Figure 4;

Figure 6 is an enlarged lateral sectional view of the portion of the pulse-jet engine, this view being taken in the direction of the arrows along the line 6-6 in Figure 4; and

Figure 7 is an enlarged rear elevational view of the portion of the pulse-jet engine, this view being taken in the direction of the arrows along the line 7-7 in Figure 4.

Referring now to Figure 1, there is illustrated a pulse-jet engine, or direct reaction motor, 10 that comprises an elongated longitudinally extending tubular section 11 of substantially cylindrical configuration and defining a primary combustion chamber 12 therein, and a forwardly converging substantially conical nose cap 13 carried by the front end of the section 11 and closing the adjacent front end of the primary combustion chamber 12 to the atmosphere. Also, the engine 10 comprises an elongated longitudinally extending and rearwardly converging tubular section 14 defining therein a secondary combustion chamber 15. The section 14 is of frusto-conical configuration; and the rear end of the section 11 is connected to the front end of the section 14, with the rear end of the primary combustion chamber 12 opening into the front end of the secondary combustion chamber 15.

Also, the engine 10 comprises an elongated longitudinally extending tubular section 16 defining an exhaust passage 17 therethrough. The section 16 is substantially cylindrical; and the rear end of the section 14 is connected to the front end of the section 16, with the rear end of the secondary combustion chamber 15 opening into the front end of the exhaust passage 17. Also, the engine comprises an elongated longitudinally extending and rearwardly diverging tubular section 18 defining an exhaust passage 19 therethrough. The section 18 is of frustoconical configuration; and the rear end of the section 16 is connected to the front end of the section 18, with the rear end of the exhaust passage 17 opening into the front end of the exhaust passage 19. The rear end of the section 18 is open, whereby the rear end of the exhaust passage 19 constitutes an exhaust gas nozzle communicating with the atmosphere. In the arrangement, the centre of the cap 13 and the longitudinal centre lines of the sections 11, 14, 16 and 18 are arranged along a common longitudinal centre line. Thus: the section 11 is disposed immediately rearwardly of the forwardly directly conical nose cap 13; the section 14 is disposed immediately rearwardly of the section 11; the section 16 is disposed immediately rearwardly of the section 14; and the section 18 is disposed immediately rearwardly of the section 16.

Further, the engine 10 comprises a plurality of elongated longitudinally extending and rearwardly directed tubular sections 20 respectively defining a corresponding plurality of inlet passages 21 therethrough; which sections 20 are arranged in an assembly disposed about the section 14 and projecting rearwardly about the section 16. As illustrated, four of the sections 20 are provided; which four sections 20 are arranged in substantially equal angularly spaced-apart relation. Each of the sections 20 comprises front and rear portions, respectively indi- cated at 20A and 20B. The front portion 20A of each section 20 projects radially outwardly and rearwardly from the common longitudinal centre line of the sections 11, 14, 16 and 18; while the rear portion 20B of each section 20 is disposed in lateral offset relation with the common longitudinal centre-line mentioned and substantially parallel thereto. The extreme front end of the front portion 20A of each section 20 is connected to the front portion of the section 14 and rearwardly of the section 11 and with the adjacent front portion of the corresponding inlet passage 21 opening into the front portion of the secondary combustion chamber 15 through a corresponding adjacent hole 22 formed in the wall of the section 14. The rear end of each section 20 is open, whereby the adjacent rear end of the corresponding inlet passage constitutes an air inlet nozzle communicating with the atmosphere. The extreme rear end of the rear portion 20B of each section 20 is outwardly and forwardly rolled to provide a reinforcing cuff 23 surrounding the adjacent air inlet nozzle.

Further, the engine 10 comprises a plurality of fuel injectors 24 respectively arranged within the front ends of the inlet passages 21 and within the adjacent front portion of 1,081,149 the secondary combustion chamber 15. Each l one of the fuel injectors 24 is orientated along the axis of the front portion 20A of the corresponding one of the sections 20 and is directed inwardly toward the rear portion of the primary combustion chamber 12 and substantially at the longitudinal centre line of the section 11. The fuel injectors 24 are respectively supported by the respectively adjacent front portions 20A of the sections 20; and the fuel injectors 24 are commonly connected to a fuel tank not shown; which fuel tank may contain any suitable liquid fuel, such as gasoline, etc. Further, the engine 10 comprises an ignition device 25, that may be in the form of a spark plug; which ignition device 25 may be arranged in a fixture, not shown, carried by the wall of the section 11 adjacent to the nose cap 13, and projecting into the front portion of the primary combustion chamber 12. The ignition device 25 is connected to a spark coil, or the like, for the usual spark purpose.

In the construction of the engine 10, the elements 11, 13, 14, 16 and 18 are formed of sheet metal such as a suitable stainless steel.

In a constructional example, the stainless steel mentioned was of the Fe-Cr-Ni type, having a thickness of 1 mm. This engine 10 has a total weight of only 37 pounds, and developed a forward thrust of approximately 250 pounds, when burning ordinary gasoline. The section 11 has an inside diameter of 240 mm. and a length of 480 mm.; and the nose cap 13 had a length of 80 mm.

The section 16 had an inside diameter of mm.; and the section 14 had an inside diameter at the front end thereof of 240 mm. and an inside diameter at the rear end thereof of 120 mm. The section 14 had a length of 240 mm.; and the section 16 had a length of 120 mm. The section 18 had an inside diameter at the front end thereof of mm. and an inside diameter at the rear end thereof of 240 mm.; and the section 18 had a length of 180 mm. Each of the sections 20 had an inside diameter of 110 mm.; the centre line of each front portion 20A was disposed at an angle of 371' to the common longitudinal centre line of the sections 11, 14, 16 and 18; and the longitudinal centre lines of oppositely disposed ones of the rear portions 20B were laterally spaced-apart by 330 mm. The rear portion 20B of each section 20 had a length of 375 mm. along the longitudinal centre line thereof.

Considering now the general mode of operation of the engine 10, and assuming starting thereof, and also assuming that there is a combustible or explosive mixture of fuel and air in the primary combustion chamber 12, the ignition device 25 is fired to cause an explosion of the mixture in the primary combustion chamber 12, whereby the explosion of the mixture proceeds rearwardly therethrough and then rearwardly through the secondary combustion chamber 15. The hot burning gases then proceed rearwardly through the tandem related exhaust passages 17 and 19 and thence through the exhaust gas nozzle at the extreme rear end of the exhaust passage 19 to the atmosphere. Of course, the rearward discharge of the gases through the exhaust gas nozzle provides a forward thrust of the engine 10 in a known manner. Some of the burning gases in the secondary combustion chamber 15 rush through the openings 22 and rearwardly through the inlet passage 21 and thence through the air inlet nozzles at the extreme rear ends of the inlet passages 21, so as to produce additional forward thrust of the engine 10; however, the amount of burning gases that rushes through any one of the holes 22 into the associated inlet passage 21 is not substantial by virtue of the abrupt offset of the front portion 20A of the associated section 20 with respect to the common longitudinal centre line of the sections 11, 14, 16 and 18. Moreover, the total length of each section 20 is substantially less than the combined lengths of the sections 14, 16 and 18.

Accordingly, the mass of rearwardly moving burning gases causes a piston effect in the secondary combustion chamber 15 and the connected exhaust passages 17 and 19; whereby a partial vacuum is created in the secondary combustion chamber 15 and in the connected inlet passages 21 prior to the complete exhausting of the hot burning gases from the exhaust gas nozzle at the extreme rear end of the exhaust passage 19. Thus, as the forward thrust subsides, the partial vacuum developed in the secondary combustion chamber 15 causes fresh air to rush into the air intake nozzles at the extreme rear ends of the intake passages 21; whereby plural streams of fresh air proceed forwardly through the intake passages 21 and are projected over the fuel injectors 24 and then directed forwardly with great turbulence into the rear of the primary combustion chamber 12 in which there is small residual burning gases. As the streams of fresh air proceed over the fuel injectors 24, the fuel injectors 24 are operated; whereby fuel is injected into the streams of fresh air, so as to produce explosive mixtures or streams of gases directed into the rear of the primary combustion chamber 12. Thus, the new mixture of gases is exploded to produce another forward thrust of the engine 10.

In view of the foregoing, it will be understood that the explosions are intermittent, and that after ignition or starting of the engine 10, the ignition device 25 is cut-off, since automatic intermittent operation or pulsing of the engine 10 is assured by the normal mode of operation thereof. In order to arrest intermittent operation of the engine it is only necessary to cut-off the supply of fuel to the fuel injectors 24, in an obvious manner.

Reconsidering the constructional example above described, it is noted that the engine had an operating frequency of approximately 80 cycles per second, as established by the dimensions of the fundamental elements 11, 14, 16, 18 and 20 thereof. In this construction, the sum of the areas of the transverse cross-sections of the inlet passages 21 measured at their points of connection to the element 14 is between 40% and 55% of the area of the largest transverse cross-section of the primary combustion chamber 12; and the sum of the areas of the inlet passages 21 may attain as much as 66% of the largest transverse cross-sectional area of the primary combustion chamber 12.

The best operation of the engine 10 is obtained when the sections 20 have a length between 70% and 100% of the length of the primary combustion chamber 12.

Referring now to Figure 2, the modified form of the pulse-jet engine 110 there illustrated is substantially identical to the pulsejet engine 10 and thus comprises the identical elements 111, 112, 114, 115, 116 and 117 as indicated. Also, in this case, the engine comprises a plurality of individual tubular parts 120A, 120B, 120C and 120D arranged in tandem relation from the front end to the rear end of the section 120. Specifically, the tubular part 120A is substantially cylindrical and is connected at the extreme front end thereof to the wall of the section 114 so that the extreme front end of the inlet passage 121 communicates with the secondary combustion chamber 115 for the purpose previously explained. The tubular part 120B is substantially cylindrical and is connected at the front end to the rear end of the part 120A. The tubular part 120C diverges rearwardly and is thus of frustoconical configuration, the extreme front end of the part 120C being connected to the rear end of the part 120 B. The tubular part 120D is substantially cylindrical and is connected at the extreme front end thereof to the rear end of the part 120C. Also, the extreme rear end of the inlet passage 121 defines in the part 120D an air inlet nozzle communicating with the atmosphere; and the extreme rear end of the part 120D is provided with a reinforcing cuff 123 surrounding the air inlet nozzle mentioned.

The general mode of operation of the engine 110 is essentially the same as that of that of engine 10 and this description is not repeated in the interest of brevity.

Referring now to Figure 3, another modified form of the pulse-jet engine 210 is there illustrated that is of the fundamental construction and arrangement of the engine 10; whereby the engine 210 comprises the identical elements 211, 212, 213, 214, 215, 216, 217, 218, 219, 220 and 221. Also the engine 210 comprises a plurality of elongated longitudinally extending sections 230 respectively defining a plurality of passages 231 therethrough. The sections 230 are arranged in an assembly about the sections 216 and 218 and are supported jointly thereby. Also, the sections 230 are respectively operatively associated with the sections 220; whereby the longitudinal centre lines of the sections 230 are substantially respectively aligned with the centre lines of the sections 220. Each of the sections 230 diverges rearwardly, whereby each of the sections 230 constitutes an aspirator providing the aspirating passage 231 therethrough.

In the engine 210, the extreme rear end of each of the sections 220 is reinforced by an associated surrounding cuff 223. Similarly, the extreme front end of each of the aspirators 230 is reinforced by an associated surrounding cuff 232.

The general mode of operation of the engine 210 is essentially the same as that of the engine 10; however, the aspirators 230 are useful in conjunction with the amplification of the thrust of the hot burning gases that are ejected through the air inlet nozzles provided in the extreme rear ends of the sections 220. Specifically, as a mass of burning gases is ejected from one of the air inlet nozzles provided in the rear end of a corresponding one of the sections 220, the same is directed into the front end of the associated one of the aspirators 230 causing a large volume of air to be drawn therewith into the adjacent front end of the aspirating passage 231 through the associated one of the aspirators 230. The hot burning gases heat the air that is thus drawn into the front end of the aspirator 230, whereby the mass of the gases in the aspirating passage 231 is expanded causing a corresponding forward thrust to be exerted upon the wall of the aspirator 230. Accordingly, the aspirators 230 assist with the production of the total forward thrust of the engine 210 in the operation thereof. Referring now to Figures 4 to 7, inclusive, a further modified form of a portion of the pulse-jet engine 310 is there illustrated that may be identical to the engine 10, except that one or more of the sections 320 is provided with an air intake scoop 350. Specifically, the air scoop 350 illustrated is carried by the extreme rear end of the secton 320 adjacent to the air inlet nozzle formed at the extreme rear end of the air inlet passage 321 extending through the section 320, the extreme rear end of the section 320 being provided with a surrounding reinforcing cuff 323 for the purpose previously explained.

Specifically, the air scoop 350 is of elon1,081.149 starting by virtue of the provision of the air scoop 350 carried by the associated section 320.

WHAT WE CLAIM IS:-

1. A pulse-jet engine comprising an elongated longitudinal extending tubular first section defining therein a primary combustion chamber, a cap connected to the front end of said first section and closing the adjacent front end of said primary combustion chamber to the atmosphere, an elongated longitudinally extending and rearwardly converging tubular second section defining therein a secondary combustion chamber, the rear end of said first section being connected to the front end of said second section with the rear end of said primary combustion chamber opening into the adjacent front end of said secondary combustion chamber, an elongated longitudinally extending tubular third section defining an exhaust passage therethrough, the rear end of said second section being connected to the front end of said third section with the rear end of said secondary combustion chamber opening into the front end of said exhaust passage, the rear end of said third section being open, whereby the rear end of said exhaust passage constitutes an exhaust gas nozzle communicating with the atmosphere, an elongated longitudinally extending tubular fourth section defining an inlet passage therethrough, one end of said fourth section being connected to the front portion of said second section with the adjacent one end of said inlet passage opening into the front portion of said secondary combustion chamber, the other end of said fourth section being open, whereby the adjacent other end of said inlet passage constitutes an air inlet nozzle communicating with the atmosphere, means for injecting fuel into said primary combustion chamber, and means for igniting a combustible mixture of fuel and air in said primary combustion chamber. 2. The pulse-jet engine of claim 1, wherein said one end of said fourth section is the front end, and the open end of said fourth section is the rear end.

3. The pulse-jet engine of claim I or 2, wherein the longitudinal axes of said first and second and third sections are arranged substantially in alignment along a common longitudinal axis, and the longitudinal axis of said fourth section is arranged in lateral off-set relation with respect to said common longitudinal axis.

4. The pulse-jet engine of claim 1, wherein said injecting means is a fuel injector disposed in said one end of said fourth section and arranged to project fuel forwardly through the adjacent front end of said secondary combustion chamber and into said primary combustion chamber.

gated longitudinally extending tubular form and defines an air passage 351 therethrough.

More particularly, the front end of the scoop 350 is open, whereby the adjacent front end of the air passage 351 communicates with the atmosphere. The rear portion of the air scoop 350 is return bent downwardly and thence forwardly, as indicated at 352, so that the extreme rear end of the air scoop 350 is also forwardly directed, with the result that the extreme rear end of the passage 351 is directed forwardly interiorly of the air inlet passage 321 extending through the section 320.

In the construction, the centre line of the extreme rear end of the scoop 350 extends downwardly and forwardly into the extreme rear end of the air inlet passage 321; and specifically, the open front end of the passage 351 and the rear end of the passage 351 are both forwardly directed, as best illustrated in Figure 6.

In the arrangement, the air scoop 350 may be suitably secured to the rear end of the section 320 and in embracing relation with respect to the associated reinforcing cuff 323.

The general mode of operation of the engine 310 is essentially the same as that of the engine 10, except in this case forward movement of the engine 310 causes fresh air to be caught in the open front end of the air scoop 350; whereby the air flows rearwardly in a stream through the passage 351, and is ultimately projected through the open rear end of the air scoop 350 and forwardly into the adjacent rear end of the air inlet passage 321 extending through the associated section 320.

The arrangement of the air scoop 350 upon at least one of the sections 320 facilitates starting of operation of the pulse-jet engine 310 in an obvious manner, assuming that the engine 310 is moving forwardly as a part of an airplane, or other forwardly moving vehicle.

At this point, it is noted in conjunction with the pulse-jet engines 10, 110 and 210 that auxiliary starting facility must be provided to initiate operation thereof. This auxiliary starting equipment may comprise one or more of the air scoops 350 as described in conjunction with pulse-jet engine 310.

On the other hand, the auxiliary starting equipment may be of any suitable form such, for example, as a cylinder of compressed air and a valve connection therefrom via one of the sections 20, 120 or 220, so as to accommodate the initial introduction into the primary combustion chamber 12, 112 or 212 of an explosive or combustible mixture of fuel and air. In other words, in the arrangements of the pulse jet engines 10.

110, 210 and 310 only the engine 310 is self1,081,149 5. The pulse-jet engine of any one of the preceding claims, wherein said fourth section has a length that is between 70% and 100% of the length of said first section.

6. The pulse-jet engine of claim 1, 2 or 3, including an elongated longitudinally extending tubular fifth section defining a scoop passage therethrough, the longitudinal axis of said fifth section being disposed in lateral off-set relation with respect to the longitudinal axis of said fourth section, the front end of said fifth section being open, whereby the adjacent front end of said scoop passage constitutes a mouth communicating with the atmosphere, the rear portion of said fifth section having a return bend therein disposed adjacent to the rear end of said fourth section, the rear end of said fifth section being forwardly directed and disposed in said air inlet nozzle, the rear end of said fifth section being open, whereby the adjacent rear end of said scoop passage constitutes an air outlet nozzle communicating with said air inlet nozzle.

7. The pulse-jet engine of claim 6, wherein the transverse cross-sectional area of said rear end of said fifth section is somewhat greater than the transverse cross-sectional area of said front end of said fifth section, and the transverse cross-sectional area of said rear outlet nozzle is substantially smaller than the transverse cross-sectional area of said air inlet nozzle.

8. The pulse-jet engine of claim 1, including a plurality of elongated longitudinally extending tubular fourth sections respectively defining a corresponding plurality of inlet passages therethrough, said fourth sections being arranged in an assembly disposed about said second section and laterally off-set with respect thereto, one end of each one of said fourth sections being connected to the front portion of said second section with the adjacent one end of the corresponding one of said inlet passages opening into the front portion of said secondary combustion chamber, the other end of each one of said fourth sections being open, whereby the adjacent other end of each one of said inlet passages constitutes an air inlet nozzle communicating with the atmosphere.

9. The pulse-jet engine of claim 8, wherein the sum of the areas of the transverse cross-sections of all of said fourth sections measured at said one ends thereof is between 40% to 55% of the area of the transverse cross-section of said first section measured at said rear end thereof.

10. The pulse-jet engine of claim 8, wherein said tubular fourth sections are rearwardly diverging, said one end of each fourth section is the front end, and the open end of each fourth section is the rear end.

11. The pulse-jet engine of claim 10, wherein said rear end of each of said fourth sections has a transverse cross-sectional area up to 120% of the transverse cross-sectional area of said front end thereof, and the sum of the transverse cross-sectional areas of said rear ends of all of said fourth sections

is about 66% of the transverse cross-section area of said first section measured at said rear end thereof.

12. The pulse-jet engine of claim 1, 2 or 3, including an elongated longitudinally extending and rearwardly diverging tubular fifth section defining an aspirator passage therethrough, the longitudinal axes of said fourth and fifth sections being disposed in substantial alignment with each other, the front end of said fifth section being disposed rearwardly of said fourth section with the adjacent front end of said aspirator passage opening to said rear inlet nozzle, the rear end of said fifth section being open, whereby the adjacent rear end of said aspirator passage constitutes a rear outlet communicating with the atmosphere.

13. The pulse-jet engine of claim 12, wherein said fifth section is supported by said third section with the longitudinal axis of said fifth section disposed in lateral off-set relation with the longitudinal axis of said third section.

14. The pulse-jet engine of any one of the preceding claims, wherein said cap and each of said sections are formed essentially of sheet metal.

15. The pulse-jet engine of claim 14, wherein said sheet metal consists essentially of stainless steel.

16. A pulse-jet engine substantially as herein described with particular reference to any one of the embodiments illustrated in the accompanying drawings. STEVENS, LANGNER, PARRY & ROLLINSON, Agents for the Applicants, Chartered Patent Agents.

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