PULSE-JET ENGINES OF THE VALVELESS TYPE

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ABSTRACT OF THE DISCLOSURE

A valveless pulse-jet engine comprising an elongated longitudinally extending tubular first section defining a primary combustion chamber, a cap connected to the front end of the first section and closing the adjacent front end of the primary combustion chamber to the atmosphere, an elongated longitudinally extending and rearwardly converging tubular second section defining a secondary combustion chamber, the rear end of the first section being connected to the front end of the second section with the rear end of the primary combustion chamber opening into the adjacent front end of the secondary combustion chamber, and an elongated longitudinally extending tubular fourth section defining an exhaust passage there through, the front end of the fourth section being connected to the rear end of the second section with the front end of the secondary combustion chamber opening into the adjacent front end of the exhaust passage, the rear end of the third section being open, whereby the rear end of the exhaust passage constitutes an exhaust gas nozzle communicating with the atmosphere, and an elongated longitudinally extending tubular fourth section defining an exhaust passage therethrough, the front end of the fourth section being connected to the rear end of the second section with the adjacent front end of the exhaust passage opening into the front portion of the secondary combustion chamber, the rear end of the fourth section being connected to the front end of the third section with the front end of the secondary combustion chamber opening into the front end of the exhaust passage, the rear end of the fourth section being connected to the front end of the primary combustion chamber, and an elongated longitudinally extending tubular fifth section defining an aspirator passage therethrough and arranged rearwardly of the fourth section and in substantially longitudinal alignment therewith, the front end of the fifth section being open so that the adjacent front end of the aspirator passage is in direct communication with the rear end of the fourth section, and the rear end of the fifth section being open so that the adjacent rear end of the aspirator passage is in direct communication with the atmosphere.

A further object of the invention is to comprise a pulse-jet engine of the character described and comprising an elongated longitudinally extending tubular sixth section defining a scoop passage therethrough, the longitudinal axis of the sixth section being disposed in lateral offset relation with respect to the longitudinal axis of the fourth section, the front end of the sixth section being open, whereby the adjacent front end of the scoop passage constitutes a mouth communicating with the atmosphere, the rear portion of the sixth section having a return bend therein disposed adjacent to the rear end of the fourth section, the rear end of the sixth section being forwardly directed and disposed in the air inlet nozzle, the rear end of the sixth section being open, whereby the adjacent rear end of the scoop passage constitutes an air outlet nozzle communicating with the air inlet nozzle.

A still further object of the invention is to comprise a pulse-jet engine of the character described, wherein the several sections thereof have advantageous relationships among the dimensions thereof.

Further features of the invention pertain to the particular arrangement of the elements of the pulse jet engine, whereby the above outlined and additional operating features thereof are attained.

The invention, both as to its organization and method of operation, together with other objects and advantages thereof, will best be understood by reference to the following specification, taken in connection with the accompanying drawings, in which:

FIGURE 1 is a longitudinal sectional view of a pulse-jet engine embodying the present invention;
FIG. 2 is an enlarged fragmentary longitudinal sec—

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 object 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 such engines of this type.

Another object of the invention is to provide a pulse-jet engine, or direct-reaction motor, subject to intermittent combustion, and provided with no moving parts, that essentially comprises an elongated longitudinally extending tubular first section defining a primary combustion chamber, a cap connected to the front end of the first section and closing the adjacent front end of the primary combustion chamber to the atmosphere, an elongated longitudinally extending and rearwardly converging tubular second section defining a secondary combustion chamber, the rear section being connected to the front end of the second section with the rear end of the primary combustion chamber opening into the adjacent front end of the secondary combustion chamber, an elongated longitudinally extending tubular third section defining an exhaust passage therethrough,
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3. A reduced longitudinal section view of a modified form of the pulse-jet engine, shown in FIG. 1;

FIG. 3 is an enlarged longitudinal sectional view of a position of the pulse-jet engine, as shown in FIG. 1;

FIG. 4 is an enlarged longitudinal sectional view of a position of the pulse-jet engine, as shown in FIG. 1;

FIG. 5 is an enlarged plan view of the portion of the pulse-jet engine, as shown in FIG. 1;

FIG. 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 FIG. 4; and

FIG. 7 is an enlarged rear elevation 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 FIG. 4.

Referring now to FIG. 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 rear end of the primary combustion chamber 12 to the atmosphere. Also, the engine 10 comprises an elongated longitudinally extending 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 forward end of the section 14, with the rear end of the secondary combustion section 15 opening into the front end of the exhaust passage 16. Also, the engine 10 comprises an elongated longitudinally extending and rearwardly diverging tubular section 18 defining an exhaust passage 19 therethrough. The section 18 is of frusto-conical 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 16 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 center of the cap 13 and the longitudinal center lines of the sections 11, 14, 16 and 18 are arranged along a common longitudinal center line. Thus: the section 11 is disposed immediately rearwardly of the forwardly directed conical nose cap 13; the section 14 is disposed immediately rearwardly of the section 16; 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 18 and projecting rearwardly about the section 16. As illustrated, four of the sections 20 are provided; which four sections 20 are arranged in substantially equidistantly spaced-apart relation. Each of the sections 20 comprises front and rear portions, respectively indicated at 20A and 20B. The front portion 20A of each section 20 projects radially outwardly and rearwardly from the common longitudinal center line of the sections 11, 14, 16 and 18; whereas the rear portion 20B of each section 20 is disposed in lateral offset relation with the common longitudinal center-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 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 the secondary combustion chamber 15. Each one of the fuel injectors 24 is oriented 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 center 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 had a total weight of only 37 pounds, and developed a forward thrust of approximately 250 pounds, when burning ordinary gasoline. The section 11 had an inside diameter of 240 mm. and a length of 480 mm.; and the nose cap 13 had a thickness of 80 mm. The section 16 had an inside diameter of 120 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 120 mm. and an inside diameter at the rear end thereof of 240 mm.; and the section 18 had a length of 1810 mm. Each of the sections 20 had an inside diameter of 110 mm.; the center line of each front portion 20A was disposed at an angle of 37°½° to the common longitudinal center line of the sections 11, 14, 16 and 18; and the longitudinal center 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 center 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...
The tubular part 120C diverges rearwardly and is thus of frusto-conical configuration, the extreme front end of the part 120C being connected to the rear end of the part 120B. 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 engine 10 and this description is not repeated in the interest of brevity.

Referring now to FIG. 3, another modified form of the pulse-jet engine 210 as 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 center lines of the sections 230 are substantially respectively aligned with the primary centerlines 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 230 is reinforced by an associated surrounding cuff 232. 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 exhaust of the hot burning gases that are ejected through the air inlet nozzle provided in the extreme rear end of the sections 220. Specifically, 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 therethrough into the extreme rear 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 FIGS. 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 section 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 elongated 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 for-
ardly directed, with the result that the extreme rear end of the passage 351 is directed forwardly internally of the inlet passage 321 extending through the section 320. In the construction, the center line of the extreme rear end of the scoop 350 extends downwardly and forwardly to 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 FIG. 6.

In the arrangement, the air scoop 350 may be suitably screwed to the rear end of the section 320 and in embracing relation with respect to the associated reinforcing stuff 322.

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 150; 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.

As 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 mixed with air for propagation therein of a primary combustion chamber, a cap connected to the front end of said first section and defining therein a primary 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, the longitudinal axes of said first and second and third sections being arranged substantially in alignment along a common longitudinal axis, said second section having a length that is about ½ of that of said first section and that is about ⅓ that of said third section, an elongated longitudinally extending tubular fourth section defining an inlet passage therethrough, the longitudinal axis of said fourth section being in lateral off-set relation with respect to said common axis, the front end of said fourth section being connected to the front portion of said second section with the adjacent front end of said inlet passage 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 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 exhaust nozzle communicating with the atmosphere.

The valveless pulse-jet engine set forth in claim 1, 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 rear inlet nozzle, and the transverse cross-sectional area of said rear outlet nozzle is substantially smaller than the transverse cross-sectional area of said rear inlet nozzle.

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