THERMOPROPULSIVE JET ENGINES OF PERIODIC COMBUSTION TYPE

Filed April 23, 1962 2 Sheets-Sheet 1

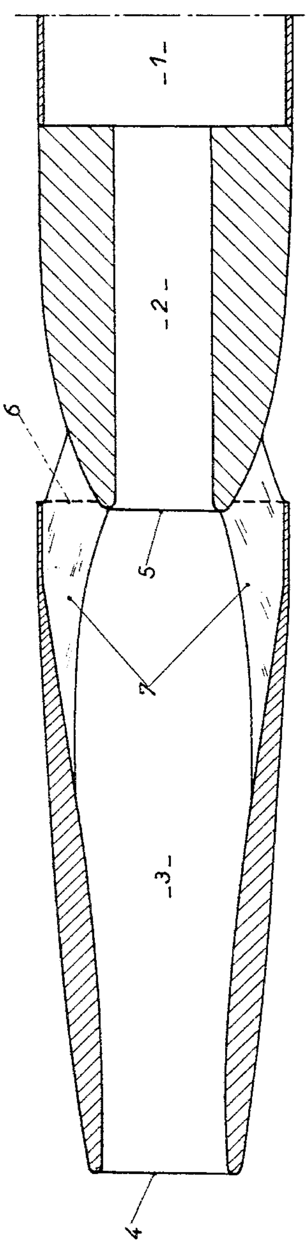

Fig. 1

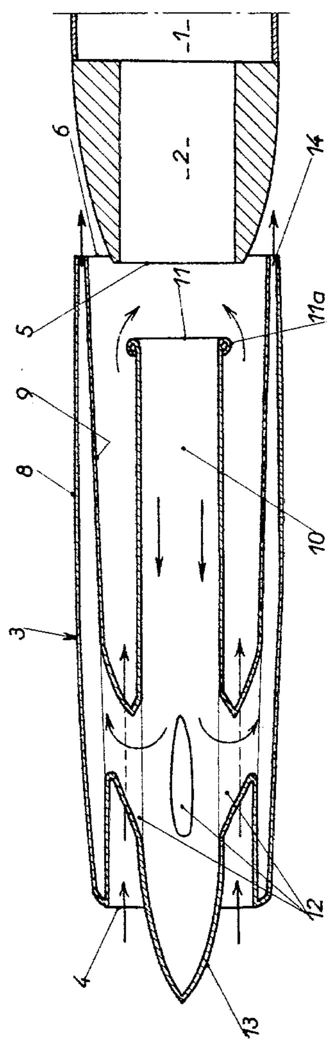

Fig. 2

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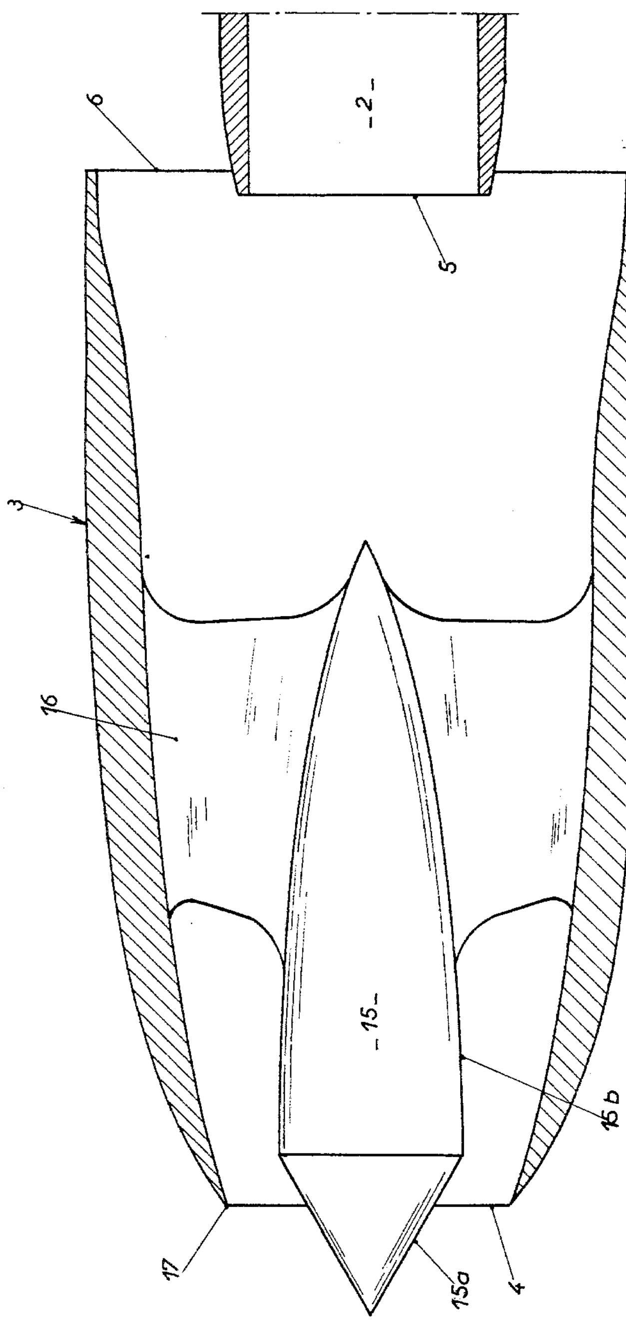

Fig.:3

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United States Patent Office 3,208,214
Patented Sept. 28, 1965

3,208,214

THERMOPROPULSIVE JET ENGINES OF PERIODIC COMBUSTION TYPE

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Filed Apr. 23, 1962, Ser. No. 189,574
Claims priority, application France, May 27, 1961, 863,115
4 Claims. (Cl. 60—35.6)

The present invention relates to pulse jet engines with or without mechanical valves, intermittent ram jet engines and wave engines, being propulsion units known by the general name of thermopropulsive jet engines of periodic combustion type.

Pulse jet engines have been applied satisfactorily in the field of low or moderate speeds for the propulsion of gliders, missiles or targets up to speeds of the order of 500 kilometres per hour. These engines, however, are subject to a loss of performance which rapidly deteriorates with an increase in the flying speed. The net thrust, that is to say the propulsive force which they are capable of transmitting to an aerodyne through the intermediary of their mountings, after their own drag has been compensated, decreases rapidly until it is cancelled out for a Mach number below 0.7.

Various solutions have already been proposed for extending the range of operation of periodic combustion type engines into the field of high flying speeds.

The basic idea to which specialists have applied themselves resides in associating the pulsatory combustion with a permanent flow passing through a fairing of a ram jet engine in the general form of a divergent-convergent element. Inside the latter there are located one or more periodic combustion engines, most frequently pulse jet engines with or without mechanical valves. As the action of the divergent portion is to decrease the velocity of the incident flow, the pulse jet engines housed inside the fairing function in an artificial atmosphere characterised by a decreased flow velocity and a higher static pressure than in the surrounding airstream.

This promising theoretical plan unfortunately presents unfavourable features which are against it in practice. One such feature is that the operation of a pulse jet engine is affected by the presence of the walls surrounding it. This is due to the fact that shock waves appear both at the inlet and at the outlet of the pulse jet engine. These shock waves are divided and reflected and intertween the pulse jet engine and its fairing. Moreover, fere in a complex manner in the flow which occurs bethey are superimposed on the shock waves produced by the succeeding cycles, so that in the end said flow deviates considerably from its ideally standing-wave character.

If we consider more particularly the flow in the upstream region of such a propulsion unit, that is to say in the front part of the fairing which forms a diffuser and is located towards the front of the pulse jet engine, it is known that the pressure oscillations caused by the latter may, if they are propagated as far as the inlet orifice of the diffuser, cause a considerable reduction in the efficiency of the transformation of the kinetic energy into pressure. This seriously affects the efficiency of the thermodynamic cycle of the propulsion unit.

It must be noted, moreover, that the phenomena are of a different nature according to whether the pulse jet engine used comprises or does not comprise mechanical air intake valves. With a pulse jet engine having mechanical valves, the phenomena are relatively simple and the pressure oscillations of moderate amplitude. In the case of a pulse jet engine without mechanical valves or

having a so-called "aerodynamic valve," on the other hand, the force of the incident shock is considerably increased by the reduction of section which generally exists between the pulsatory-combustion chamber and the air inlet nozzle or pipe. Moreover, the arrival of the shock at the inlet orifice is followed by a phenomenon of reflux of hot gases originating from the combustion chamber in the upstream direction, through said inlet nozzle.

The invention has for its object to provide an air pick-up device for pulse jet engines or other thermo-propulsive jets of periodic combustion type, enabling an engine of this kind to operate with good performances at high speeds, this device being designed to transform kinetic energy of the surrounding airstream into pressure with high efficiency without constituting any serious obstacle to the operation of the engine or causing excessive drag.

The air pick-up device of the invention comprises essentially a conduit open at both ends and acting as a diffuser located up-stream of a pulse jet engine or the like having a frontal air inlet orifice, said conduit, which extends said pulse jet engine forwardly in this way, being characterised in that its outlet section is located substantially in the plane of said frontal air inlet orifice and, preferably, very slightly downstream of said plane.

The description which follows with reference to the accompanying drawings, which are shown solely by way of non-limitative example, will make it clearly understood how the invention can be carried into effect, the details appearing both from the text and from the drawing forming, of course, part of said invention. In the drawings:

FIGURE 1 is a diagrammatic axial section of the front part of an engine according to the invention showing a simple form of construction of the air pick-up device thereof,

FIGURE 2 is a similar section showing an improved alternative construction, and

FIGURE 3 shows another modified form of construction.

In the drawings, with the aim of simplification, there is shown only a front section of the pulsatory-combustion chamber **1** of the engine with its air intake nozzle or pipe **2**, which is directed upstream and devoid of mechanical valves.

The pulse jet engine is associated with a conduit **3** coaxial with the air intake **2** and shaped as a diffuser picking up the air through an inlet orifice **4**. The air picked up is gradually slowed down with a corresponding increase in static pressure as far as the zone where an inlet section **5** of the air intake **2** of the jet pulse engine is positioned.

According to the basic special technical feature of the present invention, the diffuser **3** terminates at the rear in an outlet orifice **6** located in the plane of the inlet section **5** of the pulse jet engine or very slightly downstream of said plane, as shown clearly in the drawings. Thus, the pulse jet engine is extended forwardly by a diffuser **3** of profiled outer shape connecting up with a theoretical line representing the meridian of the body of revolution constituted by the combustion chamber **1**, but materially interrupted at **6** in the immediate proximity of the orifice **5** of the air intake **2**.

In the example illustrated, the outlet orifice **6** is annular and concentric with the inlet section **5**.

The air pick-up conduit **3** thus formed is mounted in any suitable manner, for example by means of radial profiled arms **7** (which can be seen in FIGURE 1) attaching it to the air intake **2** of the pulse jet engine.

It is known that high efficiency of transformation of the kinetic energy into pressure is fundamental for high-speed flying. This high efficiency can be attained only if the shock waves emitted in the upstream direction by the pulsatory-combustion chamber **1**—which shock waves are intensified in the case of a pulse jet engine without mechanical valves by passage through the narrowed section of the air intake **2**—cannot stem the internal flow of the diffuser **3** back as far as the inlet orifice **4** of the latter.

If the phenomena occuring in the flow limited by the walls in the region adjoining the orifice **5** of the air intake **2** are considered, it will be noted that the very rapid increase in pressure associated with the combustion causes the formation of a shock wave which passes through the air intake **2** and penetrates into the diffuser **3** where it is subdivided into a first shock wave which moves upstream in the direction of the inlet orifice **4** of the fairing and a second shock wave which moves downstream around the air intake **2** in the direction of the outlet orifice **6**.

Now, the shock waves have the property of being reflected as expansion waves at the end of a duct or channel open to the atmosphere. Such a reflection will therefore occur at the region of the outlet orifice **6** of the fairing in the case of the second shock wave moving downstream, almost immediately after the formation of the latter.

The resulting expansion wave is then directed upstream at the speed of sound and rejoins the first shock wave which continues to be propagated towards the inlet **4** of the fairing, thus gradually reducing its pressure ratio until its effect is substantially cancelled. This result is obtained even with a relatively short length of diffuser by reason of the very limited path which must be covered by the second shock wave moving down-stream to reach the plane of reflection **6**.

The fact of an expansion wave at the speed of sound catching up with a shock wave which is, by nature, supersonic constitutes a paradox only to outward appearances. In fact, the speed of the shock wave is supersonic with respect to its upstream state and, likewise, the speed of the expansion wave is that of sound with respect to its upstream state which, in the case in question, is the downstream state of the first shock wave. As the downstream state of the latter is at a temperature higher than that of its upstream state, the speed of sound is higher in proportion to the square root of the ratio of the absolute temperatures. It is this circumstance which explains the gradual overlapping of the first shock wave by the expansion wave originating from the reflection of the second shock wave.

More simply, it can be observed that if the shock wave is supersonic with respect to its upstream state, it is subsonic with respect to its down-stream state. There is therefore no impossibility in its being rejoined by an expansion wave of sonic speed with respect to its downstream state.

FIGURE 2 shows a modified constructional form of diffuser in which an annular space is formed between the outer contour wall **8** and the inner contour wall **9** of the diffuser. The latter comprises a central tube **10**, the rear orifice **11** of which is located opposite the orifice **5** of the air intake **2**. This cylindrical or slightly conical tube is coaxial with the air inlet and its cross-section may be smaller than that of the latter. The interior space of the central tube **10** communicates with the annular space between the outer contour **8** and the inner contour **9** of the diffuser **3** through the intermediary of hollow profiled arms **12** located downstream of the inlet orifice **4** of the diffuser. The central tube **10** is closed at the front by a streamlined ogive **13** which may project from the inlet orifice **4**.

The stream of hot gases ejected in the upstream direction by the air intake **2** at each combustion is collected in the central tube **10**, where it produces a resonance phenomenon, it is then conducted into the annular space between the walls **8** and **9**. Escape into the atmosphere is effected through an annular rearwardly directed slit **14** concentric with the annular outlet orifice **6** and located in the plane of the latter, or in an adjacent plane located very slightly downstream of the inlet orifice **5** of the air intake **2** as shown in FIGURE 2.

In this modified constructional form, the cross-section of the annular space between the central tube **10** and the inner wall **9** gradually increases in the downstream direction so as to decrease the flow velocity and increase the pressure. The width of the annular slit **14** is such that its cross-section is equal to, or slightly greater than, that of the inlet or rear orifice **11** of the central tube **10**. The cross-section of the space offered to the reflux flow from the orifice **11** to the slit **14** may, with advantage, be constant or increase slightly. The orifice **11** advantageously presents a rounded edge **11*a***.

The embodiment shown in FIGURE 3, which is more particularly adapted to supersonic flight, differs from that of FIGURE 1 in that the diffuser **3** comprises towards the front a central body of revolution **15** connected to the fairing by profiled radial arms **16**. In this case, the leading edge defining the inlet orifice **4** of the diffuser is in the form of a sharp edge **17**.

The body of revolution **15** may be formed by a forward cone **15*a*** the point of which projects from the inlet orifice **4** of the diffuser and which is connected at its base to a streamlined profile **15*b***, the downstream point of which is on the axis of revolution at a certain distance upstream of the orifice **5** of the air intake **2**. A cylindrical element, which is not shown, may be interposed between the cone **15*a*** and the streamlined profile **15*b***.

The central body **15** could also be constituted by a cone followed by one or more truncated cones, the small base of each of which is connected to the large base of the preceding cone or again by a continuous curved profile having a pointed leading edge such that, for the Mach number specified for the adaptation of the propulsion unit, the conical Mach waves issuing from the central body converge towards the circumference constituted by the sharp leading edge **17** of the inlet orifice **4** of the diffuser.

It is evident that, in the case of FIGURE 2, the ogive **13** will be suitably profiled according to whether the propulsion unit is designed to operate under subsonic or supersonic working conditions.

It is, moreover, a matter of course that modifications may be made in the forms of embodiment which have just been described, in particular by substituting equivalent technical means, without thereby departing from the scope of the invention.

In particular, it would be possible to fit an air pick-up device common to two or more pulse set engines having their frontal air inlet orifices located substantially in the same plane, the outlet section of the device again being located in that plane or downstream but in the immediate proximity thereof.

What is claimed is:

1. A thermopropulsive jet engine extending in a generally fore-and-aft direction, comprising a periodic combustion chanmber of the intermittent impulse type, a forwardly-projecting integral tubular extension of said combustion chamber forming therefor an air inlet of the valveless type having a forwardly-facing front end orifice and adapted to be transversed by pulses of combustion gas originating from said intermittent impulse chamber and traveling upstream to issue in a forward direction from said front end orifice, and a divergent ram intake open at both ends to the atmosphere and extending toward the front of said inlet, the rear end of said ram intake being located in a transverse plane in close proximity to said orifice, said ram intake comprising a central tube having a rearwardly opening end adjacent and opposite to said orifice, whereby gas pulses issuing forwardly therefrom are collected by said central tube, and a nozzle opening rearwardly into the atmosphere and connected with said central tube to be fed with gas collected thereby, said nozzle being located in a transverse plane in close proximity to that of said rear end of said ram intake.

2. The engine as claimed in claim **1**, wherein the nozzle extends around the rear end of the ram intake.

3. A thermopropulsive jet engine extending in a generally fore-and-aft direction, comprising a periodic combustion chamber of the intermittent impulse type, a forwardly-projecting integral tubular extension of said combustion chamber forming therefor an air inlet of the valveless type having a forwardly-facing front end orifice and adapted to be traversed by pulses of combustion gas originating from said intermittent impulse chamber and traveling upstream to issue in a forward direction from said front end orifice, and a rearwardly divergent ram intake open at both ends to the atmosphere and extending toward the front of said inlet, the rear end of said ram intake being located in a transverse plane in close proximity to said orifice.

4. An engine as claimed in claim **3**, wherein the transverse plane through the rear end of the ram intake is located slightly to the rear of the front end orifice of the inlet.

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