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JET PROPULSION UNIT COMPRISING PULSE JET UNITS
HAVING EJECTOR TUBES WITHIN A RAMJET UNIT
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Fig. 1

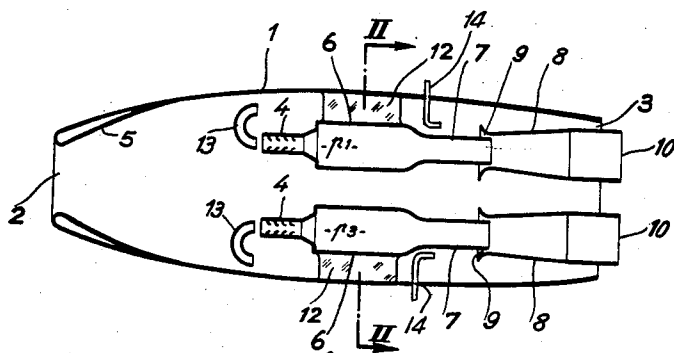


Fig. 2

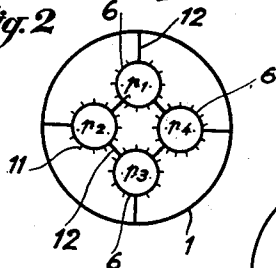


Fig. 3

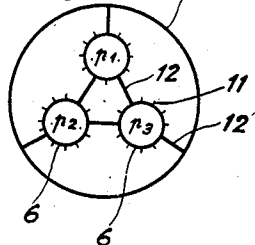


Fig. 4

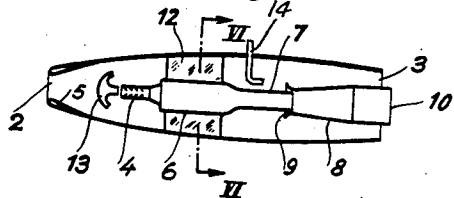


Fig. 5

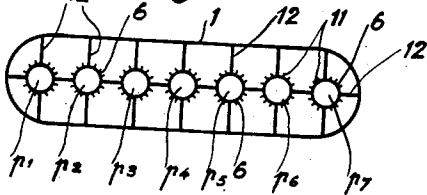
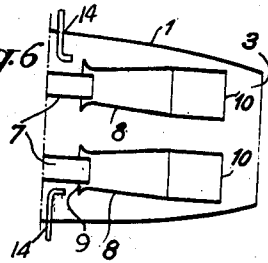


Fig. 6



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**JET PROPULSION UNIT COMPRISING PULSE JET
UNITS HAVING EJECTOR TUBES WITHIN A
RAMJET UNIT**

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Application June 5, 1951, Serial No. 229,946

Claims priority, application France October 7, 1950

2 Claims. (Cl. 60—35.6)

The known jet propulsion units are divided into three types: jet units which employ a rotating air compressor, which are known as turbo-jet units or engine-jet units, according to whether the driving of the compressor is effected by a turbine or by a piston engine; ram-jet units, also called atho-dyds, which make use of a simple thermodynamic duct and in which the air at the forward velocity of the unit is reduced and converted into pressure by a suitable shape of the inlet pipe, then heated by combustion of a suitable fuel and finally ejected at a velocity greater than the inlet velocity; and finally pulse jet units, which comprise a pulsatory combustion chamber and a nozzle which ejects the gases intermittently.

The jet units of the first type have the inconvenience that they are complicated and expensive in construction and that they wear relatively quickly.

Although the ram-jet units, which are infinitely more simple and less costly, provide a good propulsion output at high speeds, they nevertheless suffer the disadvantage that they do not give any thrust when stationary and consequently require various expedients for launching the machine to be propelled.

Finally, the pulse jet units, which are simple and inexpensive to make, are only suitable for relatively low flying speeds.

The object of the present invention is a particular combination of a ram jet duct or nacelle and a plurality of pulse jet units, such that it is possible to obtain, with the pulse jet units, a considerable thrust when stationary and consequently the self-starting of the machine to be propelled, while the propulsion output of the ram jet unit is used at high speeds.

In this combination, the pulse jet units are disposed within the ram jet duct in such a manner that the supply of the pulse jet units takes place with air at reduced speed which has traversed the ramming intake of the ram jet duct, this offering the advantage of allowing the use of a shorter air intake tube for the pulse jet unit than in the case where the latter is fed directly with air at the forward velocity of the unit. The supply tubes of the pulse jet units are preferably of the type operating with aerodynamic valves, such as those described in our U. S. Patent application Serial No. 56,582, filed on October 26, 1948, now Patent No. 2,670,011, issued February 23, 1954. Moreover, the combustion chamber of the pulse jet units is entirely situated in the central portion or intermediate space of greater cross-section of the ram jet duct (the region where the inlet of fuel and the combustion take place in ordinary ram jet units) in such manner that the heat transmitted through the wall of the combustion chamber of the pulse jet units and which is normally lost is employed to heat the air used in the ram jet cycle; finally, the outlet opening for the gases from the pulse jet units is so disposed with respect to the outlet opening of the ram jet unit that these gases react directly on the outside atmosphere or, as is possible

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in the case where there are several pulse jet units, the exhaust of the latter takes place inside the ram jet duct, a little in front of the outlet opening of the said duct.

There is thus obtained a complete and self-contained propulsion unit having considerable thrust when stationary and a satisfactory thrust characteristic as a function of the speed.

It is convenient to provide for the exhaust of the pulse jet units to take place through an ejector tube taking air from the inside of the ram jet duct and fashioned so that this air receives a part of the momentum of the gases escaping from the combustion chamber of the pulse jet units. The thrust produced by the latter is thus increased and consequently the range of action of the composite jet propulsion unit is improved. Moreover, in the combination under discussion, this arrangement allows the use of pulse jets at high flying speeds and consequently they are able to add their effect over a long range of speeds to that of the ram jet.

The ejector tube, which has been described in the patent application Serial No. 229,947 filed on June 5, 1951, now abandoned, by the applicants is of particular interest in this respect, since it permits of the dilution air being taken up in the upstream-downstream direction of flow, thus avoiding the inversions of speed which are produced when the dilution air is introduced through the outlet opening of the pulse jet unit.

The tests carried out by the applicants on pulse jet units have enabled them to determine that it is possible to take away externally some of the heat at the walls of the combustion chamber without impairing their functioning or reducing the thrust which is produced. It is thus possible to remove 40% and even 60% of the total calorific energy released by the combustion of fuel introduced into the pulse jet unit. This fact is put to advantage according to the invention for heating the air which traverses the ram jet duct. This heating may be improved by providing the outside walls of the pulse jet units with fins. The feeding of the pulse jet units through aero-dynamic valves without any moving parts has its real advantage in the fact that there is no element carrying out a reciprocatory movement. In the combination under consideration, the disadvantage which these aerodynamic valves normally have, namely, of allowing part of the gases to escape, is avoided, because it is possible to use, for heating the air of the ram jet duct, the heat carried along by these gases escaping in the opposite direction. A bent tube for turning the hot gases back into the air flow of the ram jet duct may be placed in front of each inlet tube of the pulse jet units.

Other details will be apparent from the following description taken in conjunction with the accompanying drawing which is given by way of example, it being understood that both the details described and those shown in the drawing form part of the invention.

Figure 1 is an axial section of one embodiment of a combined propulsion unit according to the invention.

Figure 2 is a transverse section on the line II—II of Figure 1.

Figure 3 is a cross section of a modification with three pulse jet units.

Figure 4 is a longitudinal section of another modification in which the ram jet duct has a flattened form and contains several pulse jet units in line (the axes of the pulse jet units disposed in the same plane).

Figure 5 is a transverse sectional view on the line VI—VI of Figure 5 of such an apparatus.

Figure 6 is a section of the outlet nozzles in a modification.

In the embodiment shown in Figures 1 and 2, the composite jet propulsion unit comprises a ram jet duct or

nacelle 1, assumed in this example to be of circular section, having its air inlet orifice at 2 and its propulsive nozzle at 3, and also four pulse jet units p_1, p_2, p_3, p_4 disposed next to each other within this nacelle. The maximum cross-section and the number of pulse jet units are suitably selected according to the section of the ram jet duct in such manner that there are spaces between the pulse jet units and also between the latter and the internal wall of the nacelle 1 of the ram jet duct in order to allow the flow of air of the ram jet duct around the pulse jet units so as to distribute the heat transmitted externally by the pulse jet units to the air of the ram jet duct.

Each of the pulse jet units comprises: an air inlet tube 4 taking in air in the ram jet duct at the place where this air, which enters at 2 at the forward velocity of the unit, has been slowed down, that is to say, after the ramming intake 5 of the nacelle 1; a combustion chamber 6 in which is effected the pulsatory combustion of a fuel introduced into the front portion of this chamber or, more generally, towards the rear of the tube 4. This fuel may be admitted in a continuous manner, as is well known, the pulsatory combustion being regulated at the frequency of the sound pipe formed by the casing of the pulse jet unit; an exhaust pipe 7 for the ejection and the acceleration of the gases produced with each combustion; an ejector tube serving for the dilution and the exhaust of the gases to atmosphere, the said ejector tube being made as described in the aforementioned patent application Serial No. 229,947, comprising a divergent section 8 following immediately after the exhaust pipe 7 but separated from it by an annular orifice 9 with a convergent entrance for the inlet of the dilution air. As set out in the said application, this ejector tube is filled with air at the depression that follows each discharge of gas and this air is forced by the gases of the following explosion which transmit to it a part of their momentum in increasing the thrust, the thrust supplement being assisted by the divergent section 8.

The dilution air entering by the annular orifice 9 is here taken from within the ram jet duct. The outlet orifice 10 for the gases and the dilution air is a little to the rear of the outlet opening 3 of the ram jet duct, so that the final exhaust of the pulse jet units takes place directly to atmosphere.

Thus advantage is taken of the property of pulse jet units of being able to operate at a fixed setting so as to supply, for the take-off, all the thrust of which they are capable, without the danger of damping, which could be produced if the exhaust of the pulse jet units took place inside the ram jet casing.

The combustion chambers 6 of the pulse jet units are disposed in that part of the fairing 1 of the ram jet duct at which, in the ordinary ram jet units, the atomisation and combustion of fuel normally take place. Thus, the heat source of the combined apparatus is constituted by the part of the heat evolved in the combustion chambers 6 of the pulse jet units, which is transmitted through the walls of these chambers. As mentioned in the introduction, this transmitted heat may be very considerable without prejudicing the functioning of the pulse jet units. Its transfer to the air circulating in the ram jet duct will be improved by fins 11 (Figure 2) arranged on the outside of the chambers 6, certain of these fins 12 being adapted to form partitions connecting the pulse jet units to one another and also securing them to the internal wall of the fairing 1.

The inlet air tubes 4 of the pulse jet units are provided with uni-directional flow control means for allowing free flow toward the combustion chambers 6 while hindering back-flow therefrom. These means are conveniently of the stationary type, and operate in a purely aerodynamic way, without any movable parts such as flap valves. Such aerodynamic valves for pulse-jet units have been de-

scribed in the above-mentioned patent application, Serial No. 56,582. However, as such tubes always allow the escape of a small part of the high temperature gases formed by each combustion in the chamber 6, it is advantageous to use these gases for the heating of the ram jet duct. For this purpose, it is possible to place, in front of each of the tubes 5, a tube section 13 which is bent through 180° in order to bring these gases back into the flow of the ram jet duct. These recuperator tubes usually have a diameter smaller than that of the inlet tube 4 and are placed at a certain distance from this tube in order not to obstruct the admission of air through the said tube.

The apparatus thus formed is a complete and self-contained propulsion unit of outstanding simplicity. An aircraft equipped with one or more of these apparatus is capable of taking off on its own without any take-off aids. Moreover, at high flying speeds, the considerable thrust of the ram jet is employed, while the pulse jet units maintain a considerable thrust by means of the dilution nozzle 8.

It is possible to provide numerous modifications of the arrangements which have been described.

In particular, there is no limitation to the number of pulse jet units. Instead of using four pulse jet units, as in Figures 1 and 2, it is possible to provide a greater or smaller number of these units. Figure 3 shows an apparatus having three pulse jet units.

The shape of the section of the ram jet duct can also vary.

In particular, it is possible to resort to a flattened shape allowing arrangement of the pulse jet units along a line or parallel lines. Figures 4 and 5 illustrate the case of a ram jet duct with a very flat fairing containing a set of pulse jet units $p_1, p_2, p_3, \dots, p_7$ arranged along a line. Such a ram jet duct can be fitted up in an aircraft wing, its air inlet being located on the leading edge of the wing, and its outlet in the vicinity of the trailing edge.

On the other hand, experiments performed by the applicants have shown that when there are several pulse jet units in the fairing of the ram jet duct, these pulse jet units are coupled automatically by making their explosions follow at regular intervals. For example, two pulse jet units are coupled in phase opposition, three pulse jet units operate with a difference in phase of

$$\frac{2\pi}{3}$$

and $(2n+1)$ units at

$$\frac{2\pi}{2n+1}$$

(n being an integer), it being convenient to have an odd number of pulse jet units. The multiplicity of pulse jet units thus makes it possible to obtain a quasi-permanent but variable exhaust flow. It is therefore possible to arrange the exhaust orifice of these pulse jet units inside the ram jet duct and a little before the outlet orifice of this duct without interfering either with the operation of the pulse jet units or with that of the ram jet duct.

An embodiment of this type is shown in Figure 6. The outlet orifice 3 of the ram jet duct is of such dimensions as to allow at the same time the combined exhaust flow of the pulse jet units and the flow of the ram jet duct. Additional heating means, e. g. fuel injectors 14, may be disposed within the ram jet nacelle in order to heat the air performing the ram jet cycle, through combustion of fuel therein. This results in a rise in temperature of this air and therefore an increased thrust.

What we claim is:

1. A composite jet propulsion engine comprising a ram jet nacelle ending with a rearwardly facing nozzle, a plurality of pulse jet units housed inside said nacelle, an ejector tube extending to the rear of each pulse jet unit

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in spaced relation with said nozzle and ending substantially in a transverse plane close to the outlet of said nozzle, at least the major portion of said ejector tubes being surrounded by air flowing through said nacelle, and means for injecting fuel into the airstream flowing through the ram jet nacelle, upstream of the ejector tubes.

2. Engine as claimed in claim 1 wherein the ejector tubes end in a transverse plane located upstream of the nozzle outlet.

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