April 19, 1960 A. W. MORLEY ET AL 2,932,944

JET PROPULSION UNIT COMPRISING AN AXIAL FLOW AIR COMPRESSOR

Filed April 18, 1955 4 Sheets-Sheet 1

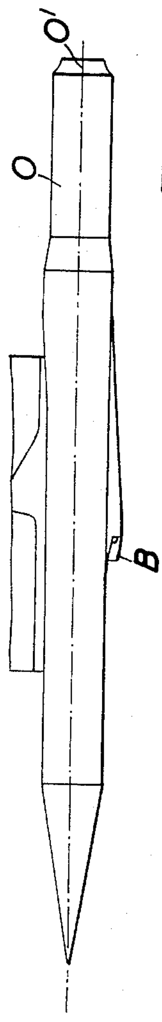

FIG. 1.

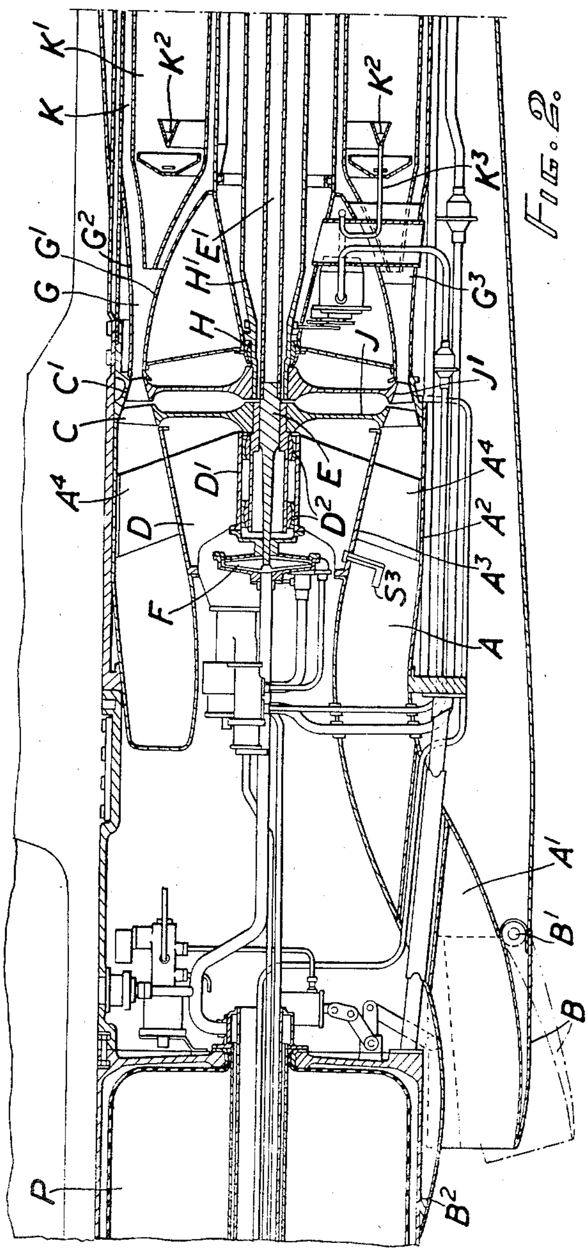

FIG. 2.

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JET PROPULSION UNIT COMPRISING AN AXIAL FLOW AIR COMPRESSOR

Filed April 18, 1955 4 Sheets-Sheet 2

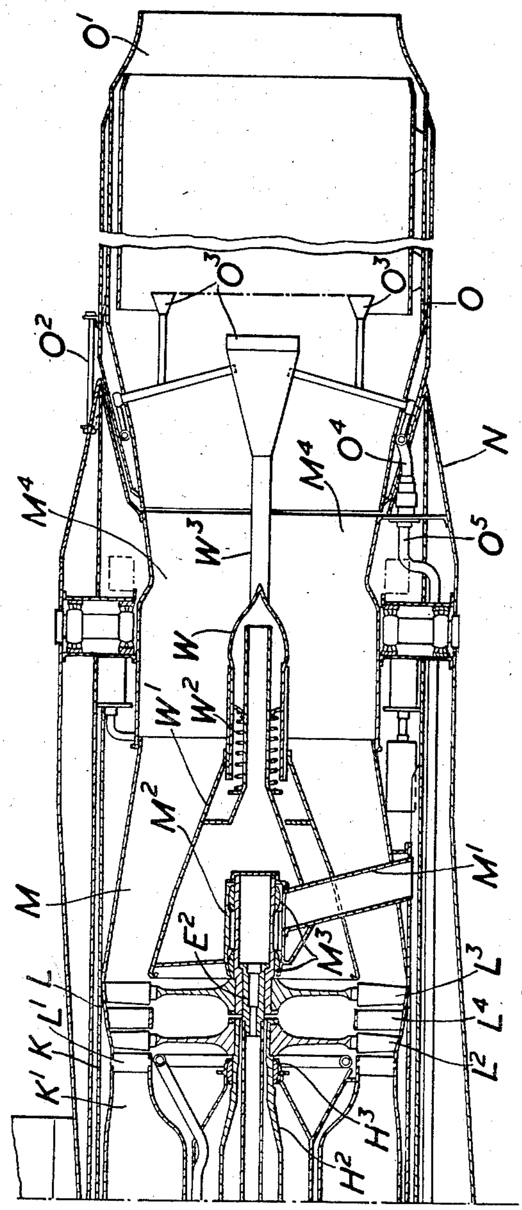

FIG. 3.

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JET PROPULSION UNIT COMPRISING AN AXIAL FLOW AIR COMPRESSOR

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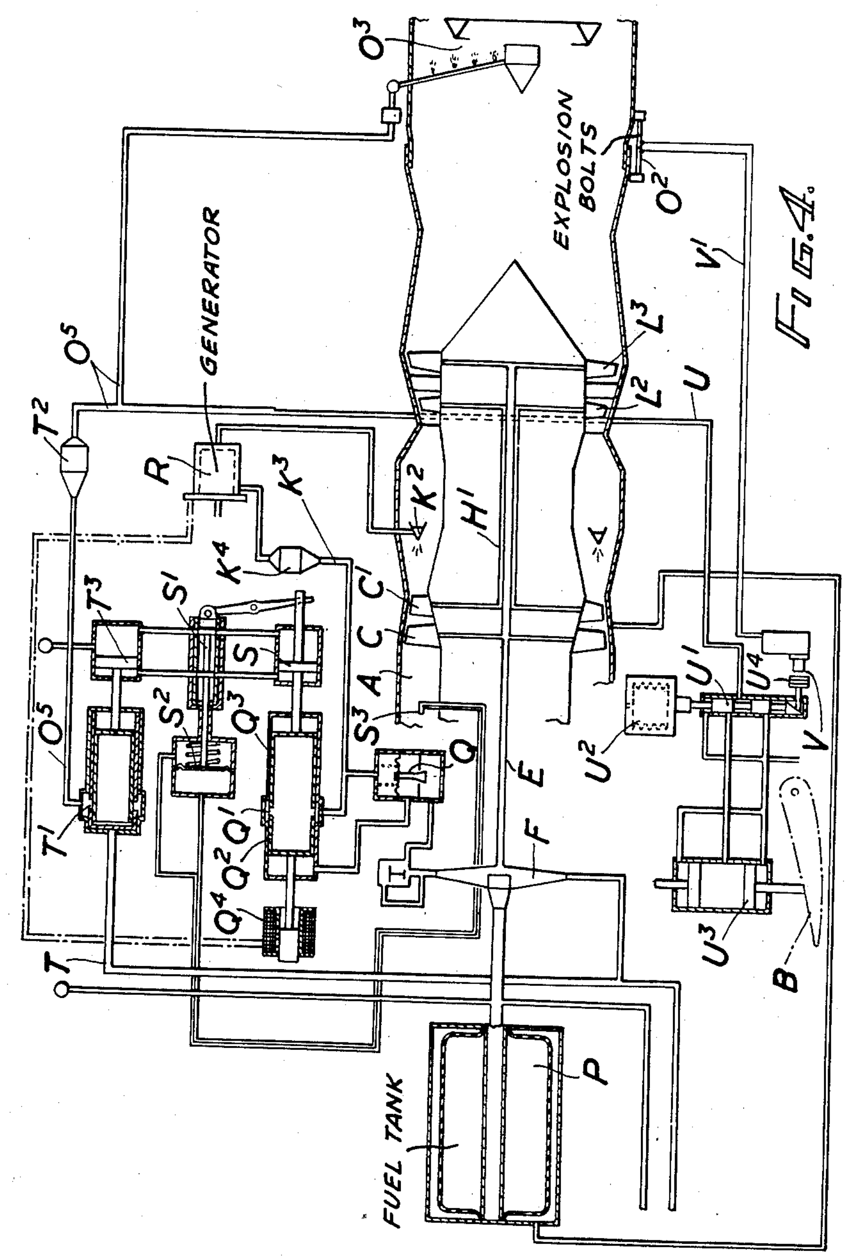

FIG. 4

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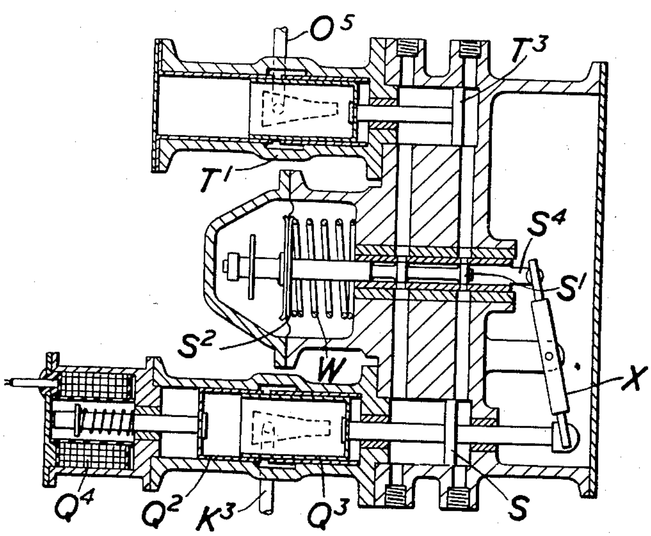

FIG. 5.

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JET PROPULSION UNIT COMPRISING AN AXIAL FLOW AIR COMPRESSOR

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Claims priority, application Great Britain April 27, 1954

1 Claim. (Cl. 60—35.6)

This invention relates to jet propulsion units of the combustion turbine type for aircraft or missiles of the kind comprising an axial flow compressor connected to the inlet end of a combustion chamber or series of combustion chambers the outlet end or ends of which are connected to the nozzle ring or equivalent of an axial flow turbine which is co-axial with the compressor, the rotors of the turbine and compressor being directly connected to one another while the products of combustion after passing through the turbine are ejected through a propulsion nozzle.

According to one feature of the invention a jet propulsion unit of the above kind comprises two rotors arranged to rotate co-axially in opposite directions and each carrying a single ring of compressor blades and a single ring of turbine blades and such that the compressor provides for two-stage supersonic compression, that is to say, compression in which the speed of movement of the blades relatively to the air is higher than the speed of sound under prevailing conditions, the unit being so designed as to obtain under normal operating conditions substantially the same predetermined Mach number condition as between the gas stream passing through the unit and the various parts on which it impinges throughout the compressor and turbine, while means are provided for controlling the fuel supply to the combustion chamber or series of combustion chambers in such a manner as to maintain said predetermined Mach number condition constant when normal operating conditions have been established.

According to another feature of the invention the unit includes a main propulsion nozzle constituting a permanent part of the unit, an extension nozzle arranged to form an extension of the main nozzle and to be held in position by releasable securing means, means for injecting fuel for so-called "reheat" purposes into the main and/or extension nozzle when the latter is attached to the former, and means for causing the connecting means to release the extension nozzle in flight after predetermined flight conditions have been achieved.

It will be understood that the term "reheat" is used in its usual sense to refer to the injection of fuel into the gases flowing to the nozzle so that it burns with unburnt air passing with the products of combustion from the turbine and thus increases the mass and velocity of the gases ejected from the nozzle.

According to a further feature of the invention the unit may include an inlet duct in advance of the compressor inlet passage and such that the flow conditions in the inlet duct are subsonic and the inlet opening at the forward end of this inlet duct therefore represents a critical area determining the mass flow into the compressor at any speed of travel of the unit through the air. Means may moreover be provided by which the area of the intake opening of the inlet duct can be increased for starting and low speed flight conditions and automatically reduced when predetermined flight conditions are reached, for example when the speed of gas flow through the unit or the speed of the unit itself through the air reaches a predetermined Mach number.

In any case the unit will normally include a fuel pump for delivering fuel under pressure through fuel control mechanism to the appropriate fuel injection nozzles, and this pump may also deliver fuel to hydraulic servo devices for performing control functions on parts of the unit or the aircraft or missile in which it is incorporated so that the fuel acts as the hydraulic fluid. In such a case a pressure-reducing valve may be provided in the fuel delivery system arranged to enable the pressure of fuel delivered to the injection nozzle or nozzles to be reduced to suit ambient atmospheric pressure conditions without appreciably affecting the pressure of fuel supplied to the hydraulic servo devices.

One form of unit according to the invention is shown somewhat diagrammatically by way of example in the accompanying drawings, in which

Figure 1 is a diagrammatic side elevation of a complete missile in which the unit is incorporated,

Figures 2 and 3 are cross-sectional views in two planes at right angles to one another, each containing the axis of the unit and respectively of the left-hand portion and the right-hand portion of the unit and may be regarded as together constituting a single cross-sectional view of the complete unit in the plane mentioned,

Figure 4 is a diagrammatic drawing of the control system of the unit, and

Figure 5 is a diagrammatic cross-sectional view of a form of fuel control device incorporated in the control apparatus of the unit.

In the construction shown the unit according to the invention is incorporated in a missile of the general, external form shown in Figure 1 and constitutes in effect the part of the unit lying in rear of about the centre of its length.

The unit comprises an annular air inlet passage A arranged to receive air through an intake passage A^1 having a forwardly facing air intake opening the outer wall of which is formed by a flap B pivoted at B^1 so that the effective area of the forwardly facing intake opening can be varied while its inner wall is formed as a rearward continuation of a short ramp B^2.

The annular inlet passage A comprises a substantially cylindrical outer wall A^2 and an approximately frustoconical inner wall A^3 supported therefrom by streamlined struts A^4, so as to provide an inlet passage of progressively diminishing cross-sectional area and progressively increasing mean diameter terminating in the annular air inlet orifice C of an axial flow compressor C^1.

The inner wall A^3 of the air inlet passage carries within it by means of webs D a bearing housing D^1 for bearings D^2 supporting the front end of a rotor shaft E which is connected to a fuel pump F also supported from the inner wall A^3 of the air inlet passage.

The rear end of the outer wall A^2 of the air inlet passage is connected to the casing of the compressor C^1 which as shown has an internal contour of short approximately frusto-conical form, the rear end of the compressor C^1 being rigidly connected to the front end of an axial diffuser G comprising coaxial inner and outer walls G^1, G^2 of which the diameter of the outer wall G^2 is approximately constant or increases slightly from its forward to its rear end while the diameter of the inner wall G^1 progressively decreases from its front to its rear end.

The inner wall G^1 of the diffuser G, which is supported from the outer wall by suitable radially extending strut members G^3 carries a bearing H for the front end of a second rotor shaft H^1 which is hollow and through which a hollow part E^1 of the rotor shaft E extends.

The rotor shaft E, E^1 supports immediately in rear of the bearing D^2 a compressor blade ring J while the rotor shaft H^1 carries at its front end and immediately behind the blade ring J a blade ring J^1. The two rotor shafts E and H are arranged to rotate in opposite directions so that the two compressor blade rings J, J^1 constitute contra rotating blade rings forming together a two-stage supersonic compressor. The rear end of the diffuser G opens directly into an annular combustion chamber casing K containing an annular flame tube or combustion chamber proper K^1 of usual form, the front end of which extends somewhat into the diffuser G as shown.

The rear end of the combustion chamber casing K is connected to a turbine casing L and the rear end of the flame tube K^1 communicates in substantially conventional manner with the nozzle ring L^1 of the turbine L.

The turbine L comprises two blade rings L^2, L^3 mounted respectively on two shafts H^2 and E^2 constituting the rear parts of the two rotor shafts E and H and separated by a stationary blade ring L^4 carried by the casing L. The outlet side of the turbine blade ring L^3 communicates directly with the front end of an annular exhaust passage M, the outer wall of which is rigidly connected to the turbine casing L and supports on struts M^1 extending radially inwards therefrom through its inner wall, a bearing housing M^2 containing a pair of spaced bearings M^3 by which the shaft E^2 is carried. It will be seen that the shaft part E^2 is connected to the shaft part E by the section E^1 which can be subject substantially only to torsion owing to the two-bearing support for each of the shaft parts E and E^2.

The rear end portion H^2 of the shaft H^1 is supported in a bearing H^3 carried by the inner wall of the casing K, which in turn is supported from the nozzle ring L^1.

The annular exhaust passage M has a mean diameter which progressively diminishes from front to rear and this passage merges into the front end of a circular propulsion nozzle passage M^5 of convergent-divergent form, terminating in a normal nozzle M^4. The portion N of the casing of the unit extends in rear of the nozzle M^4 as shown and is formed to provide a frusto conical seating for the forward end of a detachable extension nozzle element O terminating in a convergent nozzle O^1 and initially rigidly secured to the rear end of the unit by a series of explosive bolts O^2 capable of being fractured by an explosion initiated by a detonating electric current in a manner known per se.

Mounted within the nozzle M^5, M^4 is a plug-like member W arranged to slide upon the end of a structure W^1 which is rigid with the bearing housing M^2 and having a spring W^2 tending to force it rearwardly into the narrow part of the nozzle M^5, M^4. When the extension nozzle member O is in its attached position a strut W^3 carried by the nozzle member O maintains the plug-like member W in its forward position.

The arrangement is such that when the extension nozzle member O is in position the convergent nozzle O^1 constitutes the effective nozzle of the unit whereas when, owing to the explosion of the bolts O^2 the extension nozzle member O is freed from the remainder of the unit and becomes detached therefrom the nozzle M4 becomes the effective nozzle, the sudden break which occurs at the point where this nozzle terminates at the inner end of the inner wall of the extension O ensuring that the gases are ejected through the nozzle M^4 as if this represented the extreme rear end of the unit. At the same time the plug member W moves rearwardly into the narrow part of the nozzle M^5, M^4 so as to determine appropriately the effective area of this nozzle when the nozzle O has been detached.

Arranged within the extension nozzle member O are a series of fuel injection nozzles O^3 arranged to be fed with fuel through a passage O^4 which when the nozzle member O is in position communicates with a reheat fuel passage O^5 in the body of the unit the connection between the passages O^4 and O^5 being of a well known

type which when it is broken automatically causes closure of the passage O^5. Thus when the nozzle member O is released by the fracture of the bolts O^2 and the connection between the passages O^4 and O^5 breaks, the passage O^5 is closed and no further fuel is therefore delivered therethrough.

The arrangement is thus such that fuel for reheat can be delivered to the fuel nozzle device O^3 when the extension nozzle member O is in position and any further flow of fuel through the passage O^5 will be automatically stopped when the extension nozzle member O becomes detached.

It will also be apparent that the form of the nozzle member O and of its convergent nozzle O^1 can be that suited to operation of the unit efficiently with fuel for reheat supplied through the passages O^5, O^4 to the fuel nozzles O^3, for example during take off and low altitude operation while the contour and cross section of the nozzle M^4 can be such as will be suited to efficient operation without reheat fuel when the extension nozzle member O has been detached. Thus the best nozzle form and area for the two conditions of operation is provided while, moreover, during operation after detachment of the nozzle member O the whole unit is relieved of the weight of this nozzle member which not only reduces the weight to be carried but may compensate to some degree for the weight reduction near the forward end of the unit caused by consumption of fuel from the fuel tank which, as shown, is disposed at P in advance of the air inlet passage A.

Fuel nozzles for normal operation are provided as indiacted at K^2 in the combustion chamber K^1 and arranged to be fed with fuel through a feed pipe K^3.

The fuel supply and control apparatus, as shown diagrammatically in Figures 4 and 5, comprises the fuel pump F driven as explained from one of the rotors of the unit and delivering fuel through a conventional diaphragm-controlled valve Q and a variable metering orifice device Q^1, the pressure drop across which is maintained constant by the diaphragm controlled valve Q in well known manner to the fuel pipe K^3. The setting of the metering orifice device Q^1 depends upon the combined setting of two sleeves Q^2, Q^3. The position of the sleeve Q^2 is controlled electrically by an electro-magnetic device Q^4 responsive to the voltage from a speed responsive variable voltage electric generator R driven by one of the rotors of the unit so that the position of the sleeve Q^2 depends upon the rotational speed of such rotor. The position of the other sleeve Q^3 is controlled by a hydraulic servo device S the valve S^1 of which is controlled by a pressure-responsive diaphragm S^2 the opposite faces of which are responsive respectively to the total pressure head and the static pressure in the inlet passage A as derived from a Pitot tube S^3.

The pump F is arranged as shown to deliver fuel also through a passage T and a metering orifice device T^1 to the passage O^5 leading to the reheat injection nozzles O^3, a burster disc T^2 being provided in the passage O^5 designed to burst only when the pressure of fuel delivered by the pump F reaches an appropriate value. The metering orifice device T^1 is controlled by a hydraulic servo device T^3 which is also under the control of the valve S^1 so that the two metering orifice devices Q^1 and T^1 are both under the control of the valve S^1 and hence of the total and static pressures in the inlet passage A.

Fuel which flows through the metering orifice device Q^1 passes through a burster disk K^4 also arranged to burst only when the pressure of fuel delivered by the pump F reaches a suitable value, to the injection nozzles K^2 in the combustion chamber K^1, this fuel passing if desired around the electric generator R for the purpose of cooling it. Fuel from the passage O^5 is also arranged to pass through a passage U and a servo valve U^1, controlled by an aneroid capsule U^2 subject to atmospheric pressure, to a hydraulic servo device U^3 which, when pressure exists in the passage O^5 and the altitude is appropriate, serves to maintain the flap device B in the position indicated in chain line in Figure 2 so as to increase the area of the intake opening above its normal value. The servo valve U^1 and aneroid capsule U^2 are so arranged that when a predetermined altitude is reached the capsule U^2 moves into a position in which it causes the servo valve U^1 to cause movement of the flap B into the position shown in full line in Figure 2. Either at the same time or at some other altitude the movement of the valve U^1, which has an inclined cam surface at one end engaging a plunger U^4, also causes actuation of a micro-switch V which closes the detonating circuit V^1 of the explosive bolts O^2 so that the extension nozzle member O is released and the main nozzle M^3 comes into effective operation.

As will be seen from Figure 5, the fuel supply control apparatus comprising the metering orifice devices Q^1 and T^1 controlled by the servo devices S and T^3 under the control of the valve S^1 is responsive to the diaphragm S^2 subject to the total head in the inlet passage A on one face and to the static pressure in the inlet passage A and the force of a spring Z on its other face.

Moreover the ported follow up sleeve S^4 of the valve S^1 is connected by a lever X to the servo piston device S so that the movement imparted to the piston device S and hence to the sleeve Q^3 is in exact proportion to any movement of the valve S^1, while movement of the servo device T^3 and hence of the control sleeve of the metering orifice device T^1 has no direct effect on the movement of the valve S^1 but is controlled by the operation of the valve S^1 in such a manner as to tend to maintain the forces acting on the diaphragm S^2 such that the valve S^1 occupies its neutral position.

In operation the rotors of the combustion turbine unit are rotated mechanically or by forcing fluid through the unit until they reach a speed of rotation at which the pressure of fuel delivered by the pump F is such as to burst the burster disc K^4 so that fuel is now delivered to the nozzles K^2 and ignited in normal manner and self-sustained operation of the combustion turbine unit begins. The speed of the rotors then increases until the fuel pressure is sufficient to cause bursting of the burster disc T^2, whereupon fuel is also delivered to the nozzles O^3 at which time the unit is either already airborne by reason of its having been launched by catapult or auxiliary rocket apparatus, or becomes air-borne by reason of its own propulsive effort. The control of the fuel supply both at the nozzles K^2 and to the nozzles O^3 is then automatically effected by the servo devices S and T^3 under the control of the servo valve S^1, which in turn is under the control of the diaphragm S^2 and hence of the total pressure head and static pressure in the inlet passage A, in such manner that when the unit has reached a predetermined operating condition corresponding to a predetermined Mach number condition as between the parts of the unit on which the gaseous stream flowing through the unit impinges, this condition will be maintained substantially constant. During the initial period moreover, the servo device U^1, U^3 maintains the flap B in its fully open position. At a predetermined altitude, however, the aneroid capsule U^2 moves the servo valve U^1 into such position as to cause the flap B to be moved into its normal position as shown in full lines in Figure 2 in which position it is thereafter maintained. At the same time or subsequently the capsule U^2 also causes closing of the detonating circuit switch V so as to cause bursting of the explosive bolts O^2 so that the extension nozzle O is released and the main nozzle M^4 comes into effective operation, the fuel passage O^5 being automatically closed in the manner described upon separation therefrom of the fuel passage O^4.

Thereafter the unit continues in flight with the fuel supply to the nozzles K^2 controlled by the servo device S under the control of the servo valve S^1 and hence of the diaphragm S^2 in accordance with the total pressure head and the static pressure in the passage A so as to maintain constant the operating condition throughout the combustion turbine unit.

What we claim as our invention and desire to secure by Letters Patent is:

A jet propulsion unit comprising an axial flow air compressor including a compressor casing and two rotors each carrying a single ring of rotor blades, and arranged to rotate in opposite directions within the casing and constituting a two-stage compressor providing supersonic compression, at least one combustion chamber connected to receive air delivered by the compressor, means for supplying fuel to the combustion chamber, a two-stage turbine arranged to receive the products of combustion from the combustion chamber, and having two rotors arranged to rotate in opposite directions and connected directly respectively to the two rotors of the compressor, a gas outlet passage leading from the turbine and terminating in a fixed reaction nozzle of convergent-divergent form, a detachable extension nozzle including a convergent part arranged to receive the gases from the fixed nozzle and having a reaction nozzle at its rear end, releasable connecting means for securing the extension nozzle to the fixed nozzle, releasing means for causing release of said releasable connecting means and control means including a pressure sensitive device responsive to ambient atmospheric pressure and operatively connected to said releasing means to release said extension nozzle when a predetermined atmospheric pressure is reached, and a plug-like member situated within the main fixed nozzle, means carried by the extension nozzle for maintaining said plug-like member displaced from the narrow throat portion of the main fixed nozzle, and means for moving said plug-like member automatically into the narrow part of the main fixed nozzle to reduce the throat area when the extension nozzle is released.

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