July 7, 1953 H. KARLBY 2,644,301

RAM JET TURBINE

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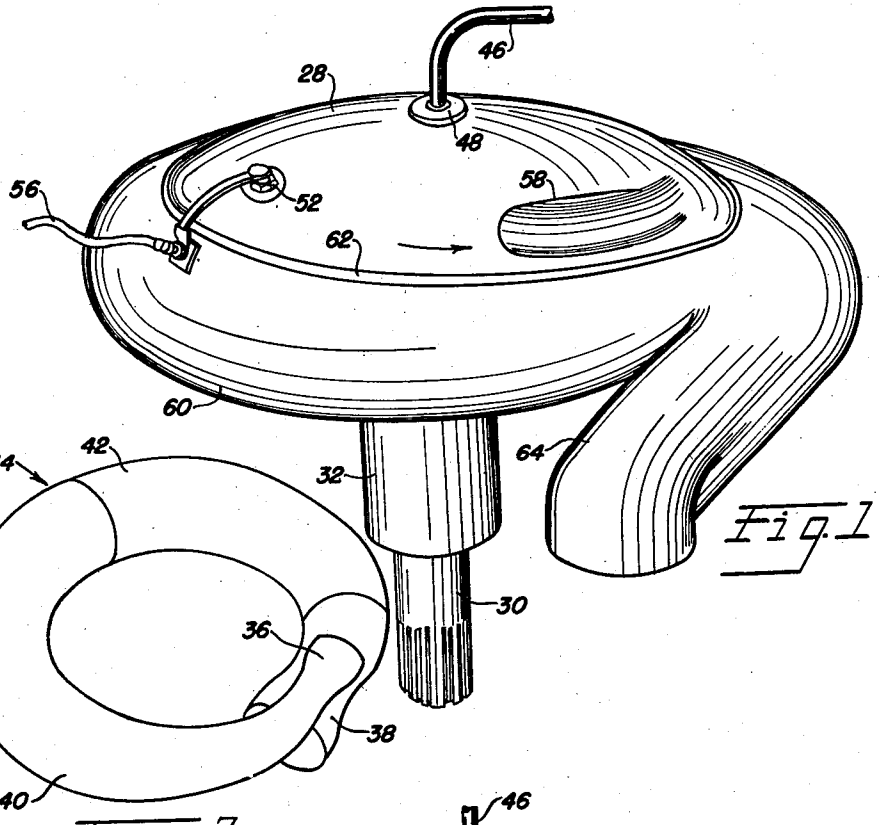


Fig. 1

Fig. 3

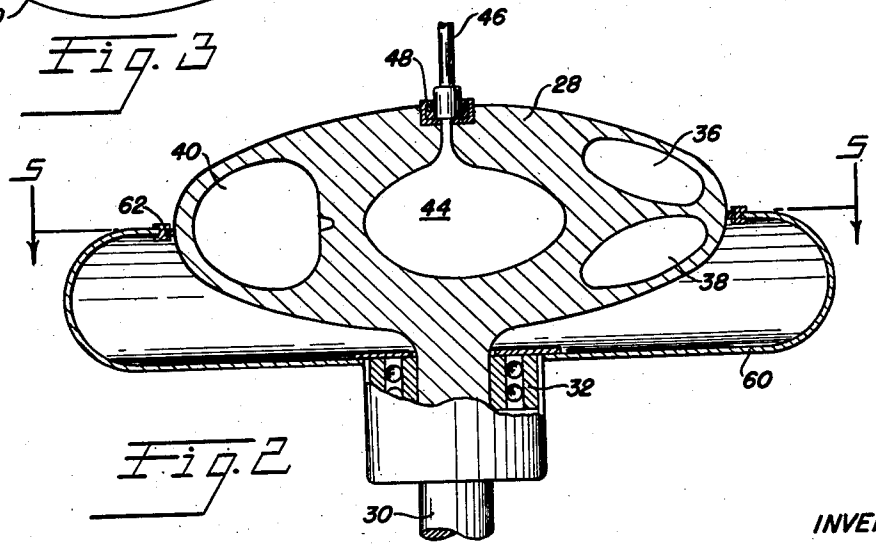


Fig. 2

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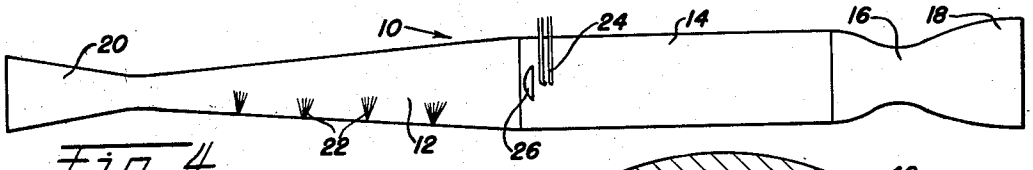


Fig. 4

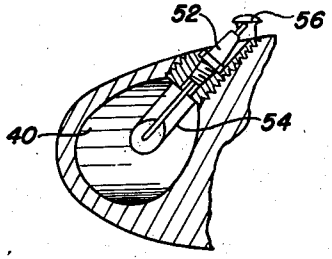


Fig. 6

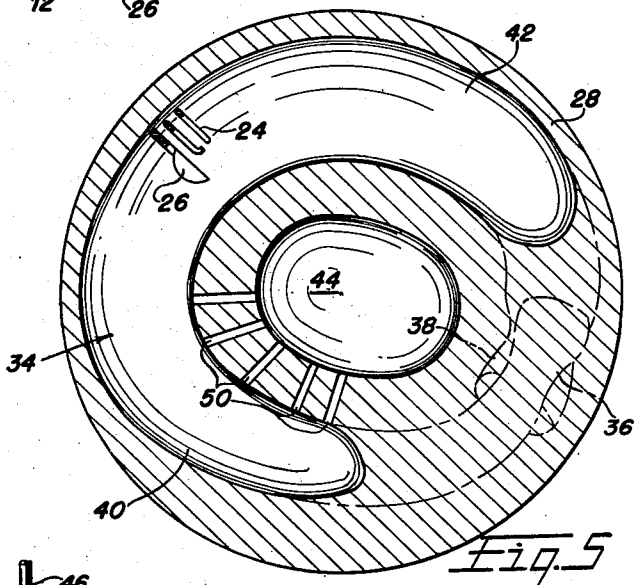


Fig. 5

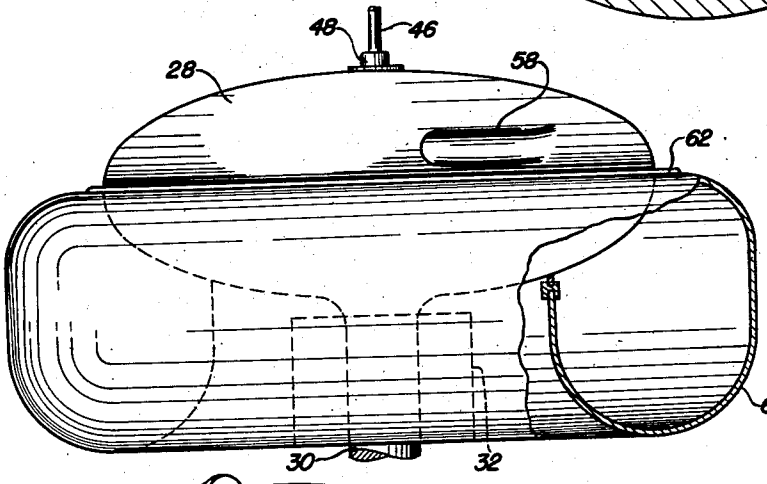


Fig. 8

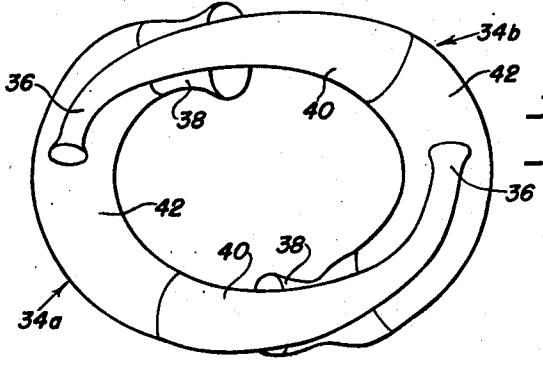


Fig. 7

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RAM JET TURBINE

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11 Claims. (Cl. 60—39.35)

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This invention relates to a ram jet turbine in which the principles of the ram jet type of engine recently developed for use in the aeronautical field are applied in a novel manner for the development of rotary power.

A prominent object of the invention is to provide a turbine rotor of very simple construction having self contained means operable by rotation of said rotor to generate high pressure gases within said body producing a propulsive effort on said body in the direction of rotation by exhaust jet action to maintain continuous rotation of the rotor at relatively high speed.

Another object of the invention resides in the provision of a rotor which is preferably in the form of a one piece casting of high heat resistant metal alloys, having one or more helical ducts formed therein concentric with the axis of rotation, and each providing an air intake compression or diffusion zone into which fuel is injected by centrifugal force, a combustion zone for the fuel and air mixture, and an expanding-exhaust jet zone producing a reactionary thrust pressure against the pressure head in the compression zone of the duct.

A further object is to provide a turbine rotor in which all external surfaces are sperically convex and the intake and exhaust end openings of the duct are substantially tangential to the peripheral surface of the rotor to prevent shock compression and reduce air drag to a minimum.

It is an additional object of the invention to provide a shroud for the exhaust end of the rotor duct, sealed to the rotor at its major dimension to prevent contamination of the intake air by the products of combustion.

The invention has for a further object, in one embodiment thereof, the provision of dual helical ducts within the rotor body, whereby the rotor will be dynamically balanced and stresses incident to angular thrust forces due to jet reaction effectively nullified.

Finally it is the aim and purpose of the present invention to provide a turbine utilizing the ram jet principle, as above characterized, which will efficiently operate at constant speed and constant torque and in which impeller vanes or other relatively moving parts are eliminated so that manufacturing and maintenance expense is reduced to a minimum.

With the above and other objects in view, the invention comprises the improved ram jet turbine and the construction and relative arrangement of its several parts, as will hereinafter be more fully described, illustrated in the accompanying drawings and subsequently incorporated in the subjoined claims.

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In the drawings, wherein I have disclosed several simple and practical embodiments of the invention and in which similar reference characters designate corresponding parts throughout the several views:

Figure 1 is a schematic perspective view showing one practical embodiment of the invention;

Figure 2 is a diametrical vertical section;

Figure 3 is a diagrammatic perspective view of the helical duct or conduit as though physically separated from the rotor body;

Figure 4 is a developed plan view of the helical rotor duct which generally corresponds in axial contour to that of the aero ram jet type of engine for generating rectilinear propulsive forces;

Figure 5 is a horizontal sectional view taken substantially on the line 5—5 of Figure 2;

Figure 6 is an enlarged fragmentary vertical section of the rotor showing the mounting of the spark plug;

Figure 7 is a perspective view similar to Figure 3 showing a dual arrangement of rotor ducts; and

Figure 8 is a side elevation partly in section showing an alternative arrangement of the exhaust receiving shroud.

The conventional ram jet type of engine as developed for producing rectilinear thrust forces to propel an aeroplane through the atmosphere at high speeds, consists essentially of an elongated tubular body comprising the fuselage structure or attached thereto, as diagrammatically represented at 10 in Figure 4 of the drawings. The axis of this engine body is coincident with or parallel to the longitudinal axis of the fuselage and the bore thereof is of varying diameter and cross-sectional area to provide a forward convergent-divergent section forming a ram compression chamber 12; an intermediate combustion chamber 14 of substantially uniform diameter; and a rear expanding chamber 16 formed with a flaring exhaust nozzle 18. The forward air entry end 20 of the compression chamber 12 has a throat of rearwardly diminishing cross-sectional area which is accurately calculated with respect to the rearwardly increasing area of the exhaust nozzle 18 for maximum operating efficiency.

As shown at 22 liquid fuel in finely divided or vaporized form is continuously introduced or injected into the chamber 12 and with the compressed air forms an intimate fuel-air mixture. Ignition means, such as a spark plug 24, and a

baffle means or flame holder 26 are arranged in the forward end of the combustion chamber 14.

Thus the ram jet engine now used as an auxiliary or substitute propulsive device for the conventional reciprocating propeller operated motor is in essence an aero-thermodynamic duct operating substantially as follows:

After the aeroplane and duct have attained a high axial velocity through the atmosphere, air entering the forward end 20 of the duct, by reason of the first diminishing and then increasing cross-sectional area, is brought to high pressure and the liquid fuel is then delivered into the rearwardly flowing air stream under relatively higher pressure to intimately mix with the air.

The high pressure, fuel-air mixture now at forward velocity almost equal to the duct velocity is then ignited and burned in the combustion chamber 14 at substantially constant pressure owing to the uniform cross-sectional area of this portion of the duct.

The high pressure, high temperature products of combustion are expelled rearwardly at velocity higher than the duct velocity through the expanding section 16 of the duct and, in expanding to atmospheric pressure through the changing cross-sectional area of nozzle 18, the resultant reactive pressure force against the pressure head in the duct section 12 is transmitted to the aeroplane through the engine structure to accelerate the forward propulsion thereof.

In the present invention I have adapted the above described principle of ram jet rectilinear propulsion to a stationary turbine engine in which the reactive pressure force of expanding gases is converted into constant rotary power for the operation of electric generators, centrifugal pumps and other apparatus.

An elemental embodiment of my new ram jet turbine is illustrated in Figures 1, 2, 3, 5 and 6 of the drawings from which it will be seen that the rotor 28 is preferably in the form of a one-piece casting of general spheroidal shape, all external surfaces thereof being smoothly merged convex arcs. The drive shaft 30 is preferably integrally formed with the rotor casting at its axis of rotation and is journalled in a suitable type of fixed bearing 32. Within the rotor body a helical duct 34 is formed in general concentric relation to the rotative axis thereof and having its air intake end 36 and expanding-exhaust end 38 circumferentially overlapped and spaced apart axially of the rotor in different planes of rotation to open upon the convex surfaces of the rotor at opposite sides of a diametrical medial plane normal to the axis of the rotor body. These end portions of the duct are shaped substantially as shown at 20 and 18 respectively in Figure 4. The duct also includes a compressor section 40 and a combustion chamber section 42, substantially corresponding in axial and cross-sectional contour to the chamber sections 12 and 14 of Figure 4.

It is essential that the rotor shall operate at the highest possible rim speed. The centrifugal bursting hot strength of the materials used, for any given shape, is proportional to the square of the rim speed. Accordingly, to conserve strength, it became necessary to construct the rotor in the form of a one-piece integral unit. This may be done by using the so-called "lost wax" method of casting highly heat resistant non-machineable metal alloys, so that the duct is formed as a cavity surrounding an axial fuel receiving cavity 44 within a smooth solid body

of revolution. The fuel supply line 46 is connected with this axial cavity by means of a conventional type of rotating seal 48 and fuel jet orifices 50 are formed through the separating wall between said cavity and the compressor and combustion sections of the duct 34. The liquid fuel is heated and partially vaporized in the cavity 44 by conduction and radiation of the heat of combustion and ejected therefrom in a finely divided state under high centrifugal pressure through orifices 50 into duct section 40 so that intimate air-fuel mixing is attained. Since, owing to difference in density between fuel and air, the centrifugal pressure on the fuel in cavity 44 will always exceed the air pressure attained in the duct section 40, the adequate delivery of atomized and partially vaporized fuel from cavity 44 is always assured.

Initial ignition of the gaseous mixture in chamber 42 of the duct may be obtained by means of a conventional spark plug 52 arranged adjacent to a baffle or flame holder 54 in the forward end of the combustion chamber 42 which shields the spark gap against wetting by the fuel spray and produces a region of turbulence to maintain a flame front as a nucleus of combustion. The plug electrode is adapted to engage the stationary contact of a high tension lead 56.

In order to minimize the effect of shock compression and attendant pressure loss, the air ingress end of the duct 34 is elongated circumferentially of the rotor to define a meeting edge with the convex surface of the rotor, as seen at 58 in Figure 1 of the drawings. Thus the air will enter the compression end of the duct substantially tangentially of the rotor.

Preferably the terminal edge of the expanding end section 38 of the duct is of similar form for the discharge of the products of combustion circumferentially of the rotor into a surrounding stationary shroud 60 which has a suitable type of running seal 62 with the rotor body at its major diameter. Where space limitations require I may use the type of shroud shown at 66 in Figure 8 of the drawings which provides an annular exhaust receiving chamber closely surrounding the drive shaft 30. The shroud, in either form thereof, may be formed with a tangentially projected duct as at 64 having an outlet which is comparatively remote from the path of rotation of the air intake end of the duct. This construction also reduces air drag to a minimum. The operation of the invention as above described is essentially as follows:

The rotor 28 is first rotated at high speed from an external source, such as an electric motor, operatively connected to the drive shaft 30. The duct 34 is thus given a high axial velocity through the atmosphere. Due to the change in cross-sectional area of the duct sections 36—40 the entering air attains a high pressure in the compression zone 40 of the duct where it is intimately mixed with the atomized and vaporized liquid fuel sprayed into the air stream under centrifugal force through the orifices 50.

The high pressure, relatively low velocity air-fuel mixture, upon entering the forward end of the central combustion zone 42 of the duct, is ignited and burned, and as this section of the duct is of uniform cross-sectional area combustion will take place at substantially constant pressure.

In the expanding-exhaust end section 38 of the duct the high pressure gases attain an absolute rearward velocity which is greater than the

initial axial forward velocity of the duct so that, when expanded back to atmospheric pressure through the rear end nozzle of the duct, a reactive forward thrust force occurs against the pressure head in the compression zone **40** of the duct to thereby transmit through the duct wall an accelerated forward rotary momentum to the rotor **28**.

In order that the speed of rotation of the rotor shall not exceed the permissible rim speed, a suitable type of governor may be provided to control the fuel supply. The electric spark ignition is required for starting only, as the established flame front will thereafter cause continuous ignition of the gaseous mixture in combustion chamber **42**. However, as an assurance against ignition failure a periodic spark may be provided, say once in each revolution of the rotor.

In order to reduce air drag resistance, which for a rotating disk is proportional to the cube of rim velocity multiplied by the square of the disk diameter, it is of first importance that the helical duct be coiled as closely as possible about the disk axis. If the maximum bursting rim speed is determined, the maximum angular bearing velocity places a lower limit on the rotor body diameter. I have determined that a maximum rotor rim speed of 2000 feet per second is feasible, and assuming a bearing speed of 100,000 R. P. M., or of the order of present day small centrifugal compressors, the lower limit on rotor body diameter is about 6 inches with a maximum thickness of about 4 inches. With such a rotor body of spherodial or lens-shaped form and devoid of shock creating free edges perpendicular at any point to the instantaneous velocities, the air drag would be of the order of 10 to 15 horse power when operating on the ram jet principle, and approximately 100 net horse power would be developed. Obviously, it is possible to construct rotors of any larger diameter desired.

This highly compact ram jet turbine must operate at a duct velocity exceeding the speed of sound in ambient air if worthwhile efficiency is to be obtained. In this case the overall efficiency (the product of thermal and propulsive efficiency) will be in the order of 5% when the duct velocity is about equal to that of sound and will increase to approximately 25% when the velocity increases to nearly twice the speed of sound, which is about that of internal combustion engines of other conventional types.

At the extreme rotor rim speeds contemplated it is imperative that the rotor body shall rotate about a major or minor axis of inertia and by making the drive shaft **30** integral with said body and of suitable mass it is possible to avoid all dynamic reactions due to rotation so that the rotor body will constantly rotate about the center of its mass. However, to assure such dynamic equilibrium and to nullify bearing side loads due to jet reaction, I may provide dual helical ducts in the rotor body as shown in Figure 7. Thus, the two ducts **34***a* and **34***b* extend in reversed helices about the axis of the rotor for about 270° with the air intake ends and the exhaust ends of said ducts respectively spaced apart approximately 180°. Therefore, the air intake end of each duct extends circumferentially beyond the exhaust end of the other duct. The axial and cross-sectional contours of the ducts are substantially the same as that above described, and it will be obvious that by this dual arrangement of ducts the rotary thrust forces of the jet reaction are effectively and equally applied to the rotor

body at diametrically opposite sides of its axis of rotation, to thereby cancel out lateral pressure forces tending to disturb the dynamic balance of the rotor.

From the above description it is believed that the construction, manner of operation and several advantages of the present invention will be fully understood. By applying the ram jet principle as herein explained for the production of rotary power, as distinguished from rectilinear thrust force, I provide a rotary turbine comprising essentially only a one-piece rotor without fragile impeller vanes or other relatively moving parts, as in the conventional engine of this type. Therefore, a material reduction in production costs and maintenance expense is realized by the present invention with the efficient development of rotary power of constant predetermined value by an engine unit of comparatively small size. The practical application and use of my new ram jet engine is therefore possible in many instances where space and weight limitations would preclude the use of the conventional reciprocatory piston or turbine type of engine.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

1. In a ram jet reaction turbine, a rotor comprising a solid body of revolution having a curvilinear duct within said body extending about the rotor axis, said duct including a single air intake and compression zone opening upon a peripheral surface of the rotor body in the direction of rotation and having a decreasing cross-sectional area in the direction of intake air flow so as to compress said air by means of ram pressure, an intermediate combustion zone, an expansion zone and exhaust end zone of varying cross-sectional area opening upon a peripheral surface of the rotor body, and means for delivering liquid fuel under pressure into said compression zone of the duct during compression of air therein by high speed rotation of the rotor to form a combustible fuel-air mixture.

2. A ram jet reaction turbine as defined in claim 1, in which the entire external surface of the rotor body is defined by smoothly merging convex arcs.

3. A ram jet reaction turbine as defined in claim 2 wherein the intake end of said duct has a terminal edge intersecting a convex external surface of the rotor and elongated circumferentially thereof in the direction of rotation to direct the entering air stream in a tangential path of flow into said duct.

4. A ram jet reaction turbine as defined in claim 1, wherein said last named means comprises a coaxial cavity in the rotor body and jet orifices discharging fuel therefrom under centrifugal force into the compressed air stream.

5. A ram jet reaction turbine as defined in claim 1, together with a coaxial drive shaft integrally formed with the rotor body.

6. A ram jet reaction turbine as defined in claim 1, wherein all external surfaces of the rotor body are smoothly convex and the open intake

and exhaust ends of said duct are disposed at relatively opposite sides of a medial diametrical plane normal to the axis of said body.

7. A ram jet reaction turbine as defined in claim 1, together with a stationary exhaust receiving shroud having a running seal with the rotor body at its major diameter.

8. In a ram jet reaction turbine, a one-piece rotor body and coaxial drive shaft of sufficient mass to dynamically balance said body and nullify the effect of thrust forces at an angle to said shaft due to jet reaction at supersonic speeds, said rotor body comprising a high heat resistant metal alloy casting having merging external surfaces convexly curved on all lines of cross-section, and a curvilinear duct formed within said rotor body defining a helix about the rotor axis, said duct including a single air intake and compression zone opening upon a peripheral surface of the rotor body in the direction of rotation and having a decreasing cross-sectional area in the direction of intake air flow so as to compress said air by means of ram pressure, a combustion zone and an expansion and exhaust zone in successive order in the direction of said flow, the intake and exhaust ends of said duct opening trangentially on convex surfaces of said rotor body at relatively opposite sides of a medial diametrical plane normal to the rotor shaft axis, and means including a fuel receiving cavity of substantial volume and a plurality of jet orifices within the rotor body for heating and centrifugally discharging liquid fuel into the compressed air stream in the compression zone of said duct.

9. A ram jet reaction turbine as defined in claim 8, together with a second curvilinear duct within the rotor body disposed at a reversed helix angle to said first duct and having the same successive order of air intake and compression, combustion, and expansion and exhaust zones, with the intake and exhaust ends of the respective ducts circumferentially spaced for approximately 180° and the intake end of one duct extending in overlapping relation to the exhaust end of the other duct.

10. A rotary ram jet engine comprising a solid

body of revolution having a curvilinear duct within said body extending entirely around the axis of rotation of the body and a separate fuel receiving cavity of substantial volume substantially in the center of the body, said duct having a single external ram air intake and an external exhaust gas discharge opening upon the peripheral surface of the body, said duct including a single, peripherally imperforate compression zone adjacent said air intake and decreasing in cross-sectional area in the direction of intake air flow to effect ram compression of said air, a combustion zone, an expansion zone and an exhaust zone of varying cross-sectional areas, means to deliver liquid fuel under pressure into said fuel receiving cavity, means to conduct fuel from said cavity into said compression zone for mixing with air being compressed therein, and means to ignite said fuel-air mixture to cause combustion thereof in said combustion zone whereby the reactive forces of the combustion products exhausting through said exhaust zone impart rotative movement to said body about its axis of rotation.

11. A ram jet engine as defined in claim 10, wherein said means to conduct fuel from said cavity into said compression zone comprises a plurality of horizontal fuel conducting ducts extending between said cavity and said compression zone.

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