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SERIES-TYPE MULTIPLE RAM JET PROPULSION SYSTEM

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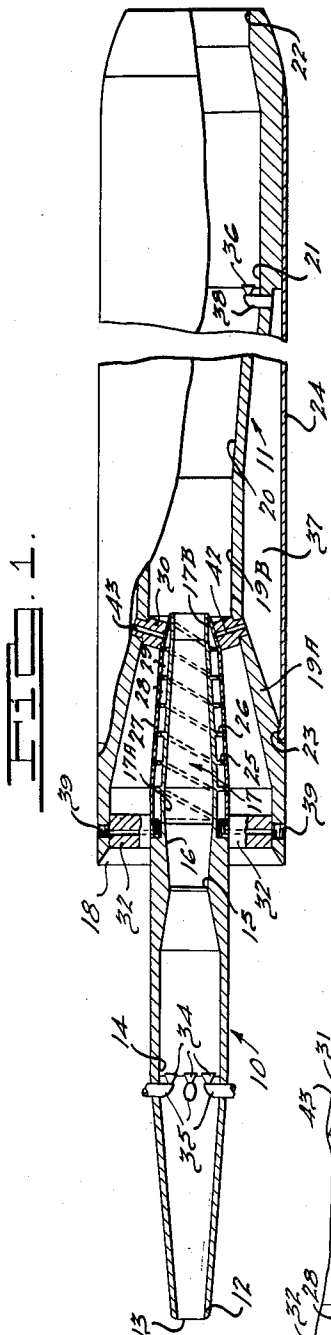


FIG. 1.

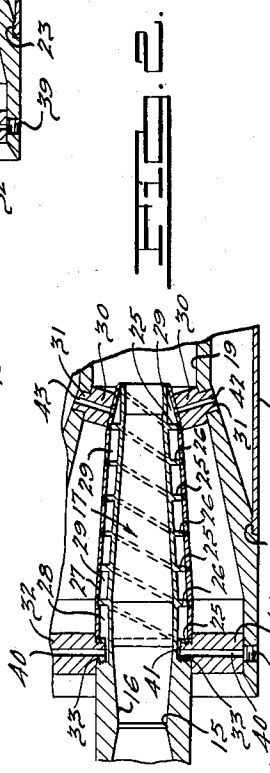


FIG. 2.

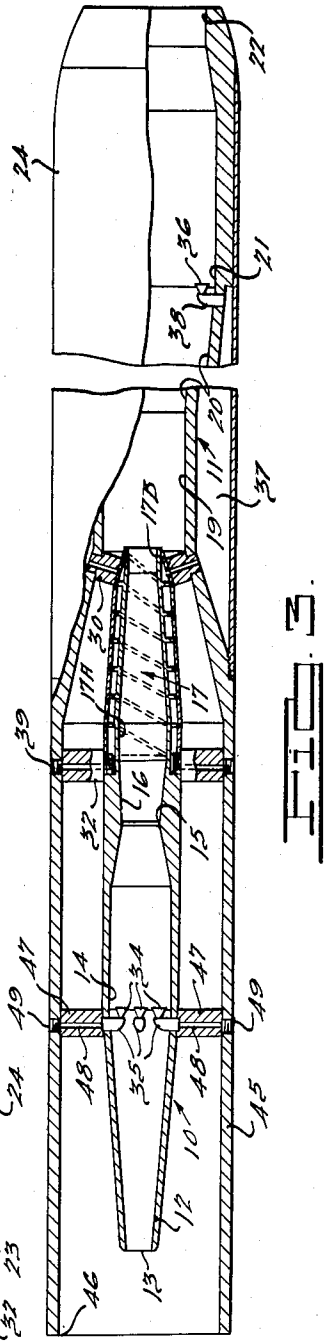


FIG. 3.

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SERIES-TYPE MULTIPLE RAM JET PROPULSION SYSTEM

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2 Claims. (Cl. 60—35.6)

This invention relates to jet propulsion power plants generally, and more particularly to power plants of the ram jet type.

Thermal jet propulsion power plants are divided into the turbo jet, pulse jet and ram jet types. The pulse jet type is very short lived in the present state of development and the present disclosure is not concerned with such type. The turbo jet presently enjoys wider use than the ram jet because in the turbo jet plant some form of rotary compressor is utilized to initially pressurize the air entering the cumbustion chamber, to thereby materially increase the velocity of the products of combustion at low air speeds. In the ram jet, which is a continuous firing unit operating with a continuous flow of air to produce a continuous propulsion thrust air is rammed from ambient atmosphere into the combustion chamber by the velocity of the unit and without the benefit of mechanical compression, and also without the use of valves or other moving parts. Such units are also known as athodyds. As used herein, throughout the specification and claims, the term "ram jet" is intended to refer to a power plant of the indicated type. With turbo jet propulsion sufficient velocity of the jet can be developed at the outlet nozzle to effect take-off of aircraft, for example, while in the ram jet type, insufficient jet velocity has thus far been developed for this purpose.

Turbo jet power plants present much greater cooling problems than ram jet types, and it has been necessary to constantly force extra air through them, resulting in considerable unburned oxygen in the exhaust. It has been proposed to obtain additional thrust by providing an after-burner of the ram jet type at the outlet of a turbo jet plant, such after-burner receiving the entire exhaust of the turbo jet and untilizing no excess air supply, so that combustion in the after-burner is supported entirely by excess oxygen from the exhaust of the turbo jet.

The present invention contemplates the provision of a novel jet propulsion power plant utilizing two or more ram jet units each of which receives its oxygen supply primarily directly from the ambient atmosphere so that although the units are arranged in tandem, the size of the second or subsequent units or stages is not limited by the size and characteristics of the first or earlier stages.

An object of the present invention is to provide a novel ram jet type of propulsion power plant providing a higher ratio of jet velocity to air speed, at relatively low air speeds, than has heretofore been obtainable with power plants of this character.

A further object is to provide a novel ram jet type of propulsion plant comprising two or more ram jets arranged in tandem, with the jet issuing from the nozzle of the first ram jet into the combustion chamber of the succeeding ram jet and drawing air from the ambient atmosphere to increase the efficiency of the latter ram jet.

A still further object is to provide a novel ram jet type of propulsion power plant of the character described in which air drawn into the trailing or intermediate ram jet is caused to enter the latter at an accelerated rate.

The above and further objects and novel features of the invention will more fully appear from the following detailed description when the same is read in connection with the accompanying drawing. It is to be expressly understood, however, that the drawing is for the purpose of illustration only and is not intended as a definition of the limits of the invention.

In the drawing, wherein like reference characters refer to like parts throughout the several views:

Figure 1 is a side elevational view, partially in section, of a novel ram jet propulsion power plant incorporating the principles of the present invention;

Figure 2 is an enlarged view of a portion of the ram jet of Figure 1; and,

Figure 3 is a side elevational view, partly in section of a modification of the novel power plant hereof.

Referring now to the drawing for a more detailed description of the present invention, and more particularly to Figure 1 thereof, the novel ram jet hereof is shown as comprising two longitudinally aligned ram jet propulsion units generally designated with the reference characters **10** and **11**. Unit **10** includes a diffuser section **12** having an inlet opening **13** which, when mounted on an aircraft, faces in the direction of motion of the aircraft, a combustion chamber **14**, a constricted throat portion **15** and a divergent partition **16** and which might, if the unit **10** were used alone, be open to discharge directly to the atmosphere. The unit **10** is used as an injector to accelerate the gases entering the second unit **11**, however, and in order to reduce the temperature of the gases delivered from the first unit to the second unit, I may incorporate a cooling section **17** consisting of a substantially straight section **17A** for reversing the diverging tendency of the gases and a section **17B** which may converge sufficiently to offset the descrease in volume and maintain the velocity of the gases. The cooling section may be cooled by a jacket structure through which the fuel is passed, and such cooling section discharges into the inlet of the after unit **11**.

Unit **11** is substantially larger than unit **10** and is preferably formed as a single unit having an inlet opening **18** at its forward end which leads into a convergent wall **19A** spacedly surrounding the rear cooling and discharge portions of the front unit **10**, around which air from the inlet **18** is thus admitted. The air from inlet **18** and gases from the front unit are led through a constricted throat portion **19B** to a divergent, pressure increasing diffuser section **20** and from there past burners **36** to combustion chamber **21** and discharge nozzle opening **22**.

The thickened wall of the unit **11** intermediate opening **18** and passage **19** is provided with a reduced peripheral portion having an external thread **23** for receiving the internally threaded end of a hollow smooth cylindrical casing or shell **24** thereon, the outer periphery of the shell being flush with the outer periphery of the supporting thickened wall of the unit so that a streamlined and unbroken surface is provided thereby. The rear end of the shell fits tightly upon the thickened rear wall of the unit and the rearmost edge of the shell is tapered so that the shell and the last-mentioned thickened wall provide a continuation of the unbroken streamlined surface. The shell also bridges the reduced intermediate portions of the rear unit **11** to provide an annular fuel feeding and inlet cooling chamber **37** through which the fuel is delivered to burners **38**.

Wall **17** of unit **10** is externally provided with two spaced helical ribs **25** and **26** of like pitch extending the length of the portions **16**, **17** and coacting with the frusto-conic outer covering rear shell portion **27** which fits tightly on the tops of the ribs to thereby define alternate spiral passages **28** and **29** between the walls **17**, **27**

and in intimate heat-conductive communication with the cooling chamber wall 17.

First ram jet unit 10 is supported within the rear ram jet unit 11 with the outlet from the rear section 17 of the front unit opening into throat portion 19 of the second unit by means of a plurality of radially arranged, spaced streamlined struts 30, the latter being provided with reduced bosses 31 at their outer ends which secure the struts within the wall of unit 11 just forward of throat portion 19 and being tightly connected as by welding with the outer periphery of shell 27 at their inner or facing ends. The spaces between struts 30 permit communication of throat portion 19 of unit 11 with the atmosphere by way of opening 18. Unit 10 is also supported by unit 11 at a point rearward of its throat 15, by a plurality of radially arranged, spaced streamlined struts 32 which have reduced externally threaded bosses 33 at their facing ends received within a series of threaded apertures formed in the wall of unit 10, the outer ends of the struts being suitably tightly fastened to the inner periphery of the wall of unit 11. The spaces between struts 32 permit passage of air from the ambient atmosphere to the interior of unit 11 by way of the spaces between struts 30.

A series of radially arranged fuel burners 34 are mounted within combustion chamber 14 of unit 10 and connected by way of supporting conduits 35 with a suitable fuel supply source (not shown) externally of the system. In a similar manner, combustion chamber 21 of unit 11 has mounted therein a series of radially arranged fuel burners 36 (one only being shown in Figure 1) which instead of being supplied directly from the fuel source are supplied instead with fuel from the chamber 37, located between the outer periphery of the wall of unit 11 and the inner periphery of shell 24, burners 36 connecting with the chamber 37 by way of conduits or pipes 38. Fuel to chamber 37 is supplied by way of suitable conduits (not shown) which are adapted for reception by a series of radially spaced tapped ports 39 formed in the wall of unit 11 adjacent opening 18. Ports 39 register with passages 40, formed in struts 32, which discharge into the helico-spiral passages 28, 29 previously referred to. One port 41 communicates with helical chamber 28 and the other communicates with helical chamber 29, the outlet of chamber 29 communicating with chamber 37 by way of a passage 42 formed in one of the struts 30 and the outlet of chamber 28 communicating with chamber 37 by way of a passage 43 in another of the struts 30. In this manner fuel passing within the relatively long passages defined by helical chambers 28 and 29 acts as a cooling agent for dissipating some of the heat of the combustion gases emerging from chamber 17 of unit 10.

Assuming the novel propulsion plant hereof to be mounted on an aircraft, for example, unit 10 will operate as a conventional ram jet. Air is rammed into opening 13 and its velocity drops and its pressure increases in diffuser section 12. At burners 34, the high pressure air is mixed with the fuel supplied by conduits 35 and burned in combustion chamber 14. The gases resulting therefrom are expanded and accelerated to pass at considerable velocity through throat portion 15 and then through the cooling passage 17 to emerge therefrom as a jet having a high velocity.

Instead of utilizing the thrust of the jet issuing from portion 17 as the means for deriving propulsion, the ram jet type of propulsion plant is improved by the present invention in accordance with which the jet issuing from discharge portion 17 passes into the second unit 11. The high speed gases leaving the front unit create a low pressure area at throat portion 19 of the second unit, thus inducing the air from the surrounding atmosphere entering opening 18 to accelerate in its passage to throat portion 19 where it continues to accelerate as it mixes with the high speed gases emanating from the front unit until the mixture reaches expansion chamber 20 of the rear unit in which the burned gases and the air are nearly at the same velocity. As the latter mixture approaches combustion chamber 21, its velocity decreases and its pressure increases, the pressure reaching a maximum value at burners 36 where fuel from conduits 38 is sprayed into the mixture and burned by the burners. The resulting burned gases are expanded and accelerated through nozzle 22 attaining a maximum velocity as they issue as a jet from the nozzle.

It will now be apparent that by the novel arrangement hereof the discharge first ram jet unit is utilized not merely for thrust purposes, as in conventional power plants, but for increasing the entrance velocity of the atmospheric air to the second combustion chamber which of course not only increases the velocity of the jet issuing from nozzle 22 of the latter chamber but also aids in total combustion within the second combustion chamber. Obviously other stages may be used in addition to the two stages shown, whereby the use of one stage to increase the velocity of the next will increase the maximum pressure of the latter stage and thereby increase the overall efficiency of the plant. While the increased entrance velocities will increase the entrance temperatures, a net gain will be obtained nevertheless because as more stages are utilized the higher will be the maximum pressure in the last stage.

The length of throat portion 19 must be great enough so that the air and the burned gases will be moving at substantially the same velocity when they reach expansion chamber 20. The cross-sectional area of the throat 19 is only varied throughout its length sufficiently to take care of variations of volume of the mixture due to temperature change and variations of velocity of the burned gases and air as they approach a common velocity. The air will increase in volume at about the same rate that the burned gases decrease in volume during the transfer of heat in mixing so that the total volume will remain about the same. Similarly, the increase in velocity of the air is offset by decrease in velocity of the burned gases so that the cross-sectional area between the two sections will be about constant.

Instead of using the jet issuing from the first combustion chamber only to accelerate the air entering the second combustion chamber, it could be used to also accelerate the air rammed into the first combustion chamber. To this end, the modification of Figure 3 is utilized in which the entrance opening 18 of the second chamber is replaced by a shell 45 which extends forwardly in the form of a shroud over the front unit and terminates in an opening 46 forward of opening 13 of diffuser section 12. In this event, the first combustion chamber is supported adjacent its combustion chamber 14 by a plurality of spaced radial streamlined struts 47 having passages 48 formed therein which register at their facing ends with conduit-supports 35 of burners 34 and at their opposite ends with tapped ports 49, formed in shroud 45 to thereby convey fuel from the source to the burners. In all other respects the arrangement is generally similar to the arrangement of Figures 1 and 2.

With the arrangement of Figure 3, air is initially rammed into chamber 12 and the pressure increases here and in combustion chamber 14, where the fuel is mixed with the air and burned and the burned gases thereafter expelled through cooling-discharge chamber 17 to the second unit. In leaving the first unit, the issuing jet develops a low pressure area at the forward end of throat portion 19 whereupon the air entering opening 46 of shroud 45 is accelerated not only to enter the second combustion chamber by way of the spaces between struts 30, 32 and 47 but also to enter the inlet 13 of the front unit. Thus, by virtue of the accelerated air entering the first unit, the jet issuing from it will be at a correspondingly greater velocity to ultimately increase the velocity of the jet issuing from nozzle 22.

There has thus been provided a novel ram jet pro-

pulsion power plant in which two or more ram jets may be arranged in tandem with the nozzle of the first jet discharging into the succeeding ram jet whereupon air will be drawn at an accelerated rate into the succeeding combustion chamber to assist in total combustion of the fuel and to increase the velocity of the ultimate issuing jet, the first jet also being adapted for use to accelerate the air rammed into the first combustion chamber.

Although two embodiments of the invention have been illustrated and described in detail, various other changes and modifications in the construction and relative arrangement of the parts, which will now appear to those skilled in the art, may be made without departing from the scope of the invention. For example, while pairs of diametrically arranged supporting struts have been shown, any number of radially spaced struts could be utilized equally as well.

What is claimed is:

1. A jet propulsion power plant comprising first and second thrust generating ram jets, each of said ram jets having an inlet nozzle, a combustion chamber, and an outlet nozzle, the inlet nozzle of the second ram jet comprising an injector throat surrounding and greater in diameter than the outlet nozzle of the first ram jet, the second ram jet having a pressure-increasing diffuser section interposed between the inlet nozzle and the combustion chamber, means for injecting fuel into said combustion chambers, means for supporting the first and second ram jets in substantialy coaxial tandem relationship with the outlet nozzle of the first ram jet projecting into the interior of the second ram jet to a point substantially adjacent the said injector throat and communicating with the diffuser section and the combustion chamber of the second ram jet, the inlet nozzle of the second ram jet communicating with the atmosphere forwardly of the rear extremity of said outlet nozzle of the first ram jet.

2. A multi-stage jet type power plant comprising substantially coaxial first and second thrust generating ram jet units, each of said units having an input portion, a combustion chamber, and an output portion, the second unit having a pressure-increasing diffuser section interposed between the input portion and the combustion chamber, means for injecting fuel into said combustion chambers, the output portion of the first unit opening directly into the input portion of the second unit, the input portion of the second unit comprising an injector throat surrounding the output portion of the first unit and communicating with the atmosphere forwardly of the rear extremity of the output portion of the first unit, each unit having burner means located to the rear of its input portion.

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