Feb. 5, 1963 D. H. SWEET 3,076,308

RAM JET UNIT

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Fig. 1.

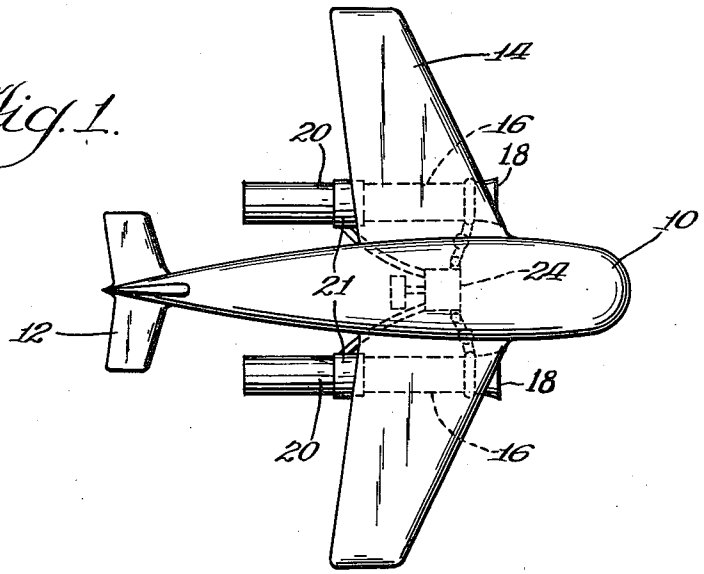
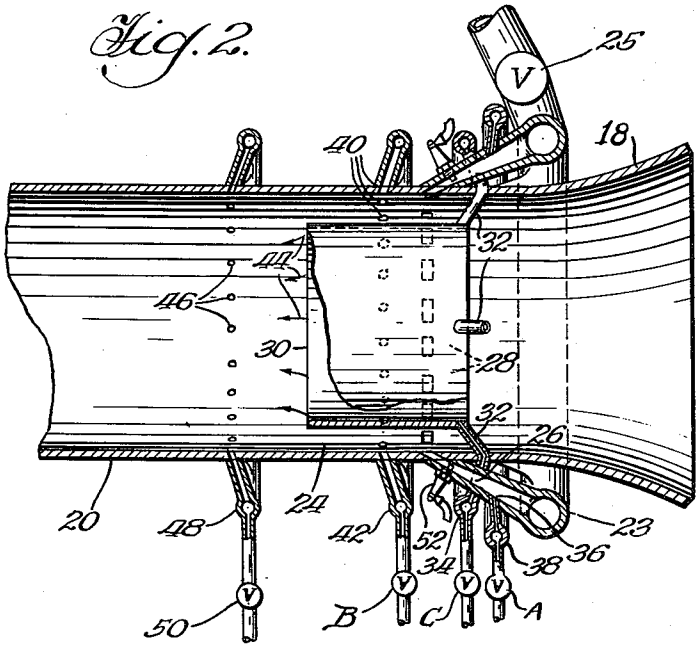


Fig. 2.



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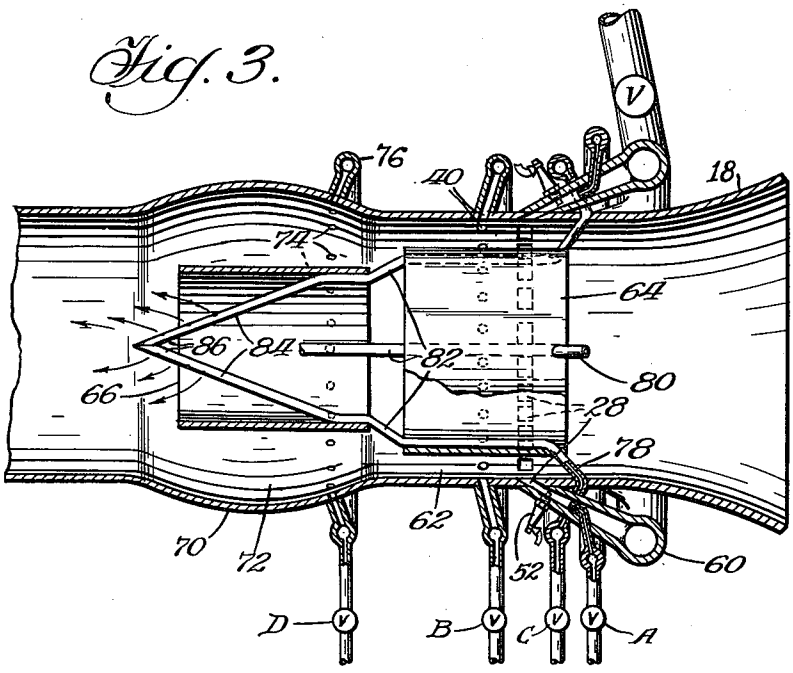
Donald H. Sweet

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Fig. 3.



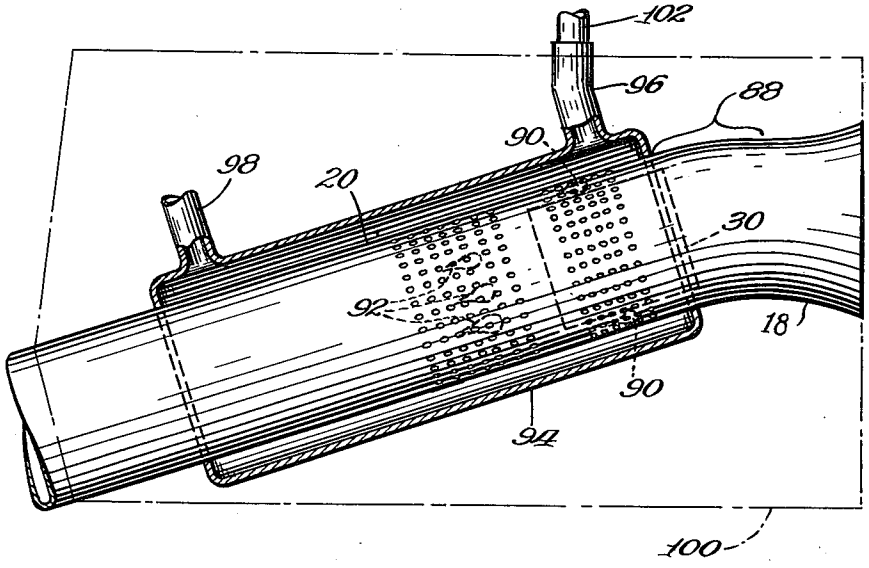


Fig. 4.

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3,076,308

RAM JET UNIT

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6 Claims. (Cl. 60—35.3)

My invention relates to aviation and particularly to a jet device for generating thrust. It includes among its objects and advantages, means for generating relatively high thrust at a relatively small fraction of cruising speed, and automatic transition from low speed, high condition, to normal cruising conditions.

In the accompanying drawings:

FIGURE 1 is a diagrammatic plan view of a conventional airplane, indicating the application of a power plant according to the invention thereto;

FIGURE 2 is a longitudinal central section of the combustion portion of a two-stage jet;

FIGURE 3 is a similar section of a three-stage jet; and

FIGURE 4 is a side elevation of a jet tube proper with a jacket in section and a housing contour indicated.

In the embodiment of the invention selected for illustration, the fuselage 10, empennage 12 and wings 14 may be conventional. The twin jet units 16 may be faired into the wing in a conventional way. They are located closely adjacent the front end of the fuselage 10 where the compression set up by forward movement of the fuselage contributes to the impulse of the entering stream. Each jet unit comprises an intake cone 18 performing the conventional function, and an expansion tube 20.

The booster plant 24 in the fuselage is a simple air compressor. Depending on operating conditions and required top speeds, its power may vary from about two to about ten percent of the power of the jets at cruising speed. Thus an aircraft using two jets designed to develop 4,000 horsepower each at cruising speed may be provided with an air compressor 24 of from two to eight hundred horsepower. The air compressor may be a positive displacement unit or a rotary impulse unit of the type illustrated in U.S. Patent 2,439,273, issued April 16, 1948, on an invention by A. G. Silvester. In employing a plant of this type for the present purpose, however, the fuel supply to the compressor unit will be reduced to a minor fraction of what would be used if it were the main power unit. Where an internal combustion unit is used to power either an impulse or a positive displacement booster, the products of combustion will be piped into the discharged air compressed by the unit. Thus the material delivered will be highly ionized because it will contain a substantial percentage of the products of very recent combustion, but only a minor fraction of the available oxygen will have been consumed, leaving the compressed product available to support further, rapid combustion as well as to accelerate into a jet.

Referring now to FIGURE 2, I have illustrated a manifold 23 receiving the compressed gases from the booster power plant 24. The manifold 23 is in open communication with a series of tapering nozzles 26 debouching through jet openings 28 near the inlet end of the tube 20. To segregate the gases subjected to the impact of the jets at 28 and limit them to a volume that can be effectively entrained by the amount of material available in the jets, I provide a segregating tube 30 concentric with the tube 20 and defining an annular passage beginning a little upstream above the jets 28 and extending downstream several times as far. The segregator 30 may be supported by braces 32 at its front end where they will not be subjected to flame, and at least one of the braces 32 communicates with a fuel conduit 34 controlled by a supply valve C.

The nozzles 26 are also each provided with a fuel supply tube 36, which supply tubes take from a common manifold 38 with the feed controlled by a supply valve A. I provide an additional series of fuel inlets a little downstream from the jets 28 as indicated at 40, and these are supplied from a manifold 42 and controlled by fuel supply valve B. The fuel jets supplied by conduit 34 may debouch from the downstream end of the segregator 30 at points indicated at 44. I also provide a series of fuel jets 46, downstream from the downstream end of the segregator, supplied from the manifold 48 under the control of supply valve 50.

In considering the thrust characteristics of such a unit, it is to be borne in mind that much lower relative speeds, compared with the unit itself, are required in starting, to generate substantial thrust, enough to produce fairly rapid acceleration. For instance, in a unit designed to cruise at 400 miles per hour, the cruising unit receives the incoming gases at 400 miles per hour, and may expel them at a relative velocity of 1200 miles per hour, with a net rearward velocity of 800 miles per hour. To give the same acceleration to gases starting from rest, it is only necessary to accelerate them in the jet to a relative velocity of 800 miles per hour, and if the entrance velocity is 100 miles per hour an exit velocity of 900 miles per hour will still achieve the same thrust per unit of mass. Of course, the volume of gases entering the jet is less at low speeds, but with a jet capable of getting the gases in it up to exit velocities of the order of magnitude of 1200 miles per hour, this lesser volume can be offset by delivering what material is available at substantially full speeds. This would be impossible without the pressure cushion set up by the booster plant. With the relatively small stream, the power of the booster is a so much larger proportion of the available power that substantially full relative discharge velocities, corresponding to rearward accelerations in excess of normal, can be achieved by forcing the jets at and just before take-off. At, say, one-third of cruising speed, with air resistance about one-ninth of cruising values, this leaves a good margin of thrust for acceleration.

In operating a power plant according to the invention, the operator first starts the booster plant 24. As soon as that is running smoothly, the valves 25 leading to the manifold 23 are thrown wide open, and the jets 28 begin to function. Immediately thereafter, fuel supply valve A is opened and energy is supplied to spark plugs 52 in the jets 26 to start combustion. The velocity in the jets 26 will be such that most of the burning of the fuel controlled by valve A will take place during and after the exit of the material into the segregated annular passage 24 between the segregator 30 and the main tube 20. The impact of the jets 28 on the much larger mass of gas in the accelerating passage 24 will generate a pressure zone surrounding and immediately downstream from the jets 28, which pressure zone must be maintained as a cushion to carry the force of expansion due to the burning of the combustible material. As soon as a flame is established in the passage 24, the operator opens control valve B and feeds to that flame an amount of fuel about five or ten times as great as that supplied through control valve A. This fuel may be sufficient to utilize a major fraction of the available oxygen, not only from the jets 28, in which only a minor fraction of the oxygen has been consumed so far, but in the gases entrained by the jets 28. With the pressure cushion set up by the jets 28 as a springboard, this larger flame pushes down the main tube 20 and establishes a strong discharge and a heavy suction at the intake end, along the axis and inside the segregator 30, with a second pressure zone just down stream below the segregator.

The operator is now ready to start his run, which he does by opening control valves C and injecting at points **44** atomized fuel under high pressure in amounts from two to ten times as great as those being supplied through control valve B, and in increasing amounts as the speed increases and the growing volume of the stream inside the segregator **30** supplies the necessary oxygen. It will be apparent that the entraining action of the flame issuing from the space **24** generates a strong but not unlimited force to draw the gases along the tube, and that during the early stages of acceleration a premature excess supply to the jets would generate pressure that might reverse the direction of flow inside the segregator **30**.

The practical effectiveness of the booster power source needs to be stated in figures to be appreciated. For instance, with a unit designed to deliver 4000 horse power at a cruising speed of 500 miles per hour, a thrust of 3000 pounds corresponds to 4000 horse power, and an extra 200 horse power from the booster would only add 150 pounds more. But at a standstill at sea level, 200 horse power issuing in a 36-inch stream from the tube **20**, amounts to 757 pounds of air per second, delivered at 73 miles per hour, with a thrust of 2530 pounds. Ample thrust for initial acceleration can be obtained with the booster alone even without burning any fuel at all, and enough fuel to get an expansion of 41 percent in the tube, would double the power and the thrust. As speed is attained, this large booster thrust dwindles rapidly, but at all speeds, the reduction can be more than replaced by the true jet thrust due to combustion.

Take-off is preferably made with the booster plant **24** operating on wide open throttle and jets **40** and **44** delivering all the fuel the air can consume. Supply jets **36** may continue to discharge at their original normal volume. In terms of total volume, they constitute a negligible contribution to power as soon as the larger jets begin functioning, but the ionized air they deliver will accelerate the speed of combustion at the upstream ends of the large flames. To increase this supply of ionized gas, part or all of the air compressed by the booster plant **24** may be taken from the burnt gases in the main tube **20**, as by means of manifolds **21** (see FIGURE 1.).

After take-off the same condition may be maintained briefly until desired climbing or cruising speed is attained, and by that time the continual increase in the large jets has transferred to jets **44** some 70% and to jets **40** some 24% of the load. Thereafter it would be possible to shut down the power plant **24**, but it is preferable to keep it running at about one quarter of its load capacity. Valve A can advantageously be closed completely, and valve B cut down materially, with the advantage that the gases moving rearwardly will include a relatively cool layer next to the tube **20**.

For rapid climbing, or forcing the plane to maximum speed for emergency reasons, power plant **24** can be run up to full load, but preferably with almost no fuel in the jets **28**. Jets **40** can be operated at medium capacity to get the air ionized for rapid combustion. The bulk of the fuel will be in jets **44**, and the last of the oxygen capacity in the stream may be used up by the jets **46**.

Referring now to FIGURE 3, I have illustrated a three-stage burning arrangement intended for relatively heavy transport duty, compared with the jet of FIGURE 2. The manifold **60** corresponds to the manifold **23** of FIGURE 2 and supplies the same type of jet to the first booster passage **62** separated from the center by the segregator **64**. The same fuel valve A provides the starting fuel, and the same fuel valve B provides the supply for the booster flame below the jets in passage **62**. Below the segregator **64** I provide a second segregator **66** defining, between itself and the main tube, an outer annular area from about two to five or ten times as great as that segregated by the segregator **64**. To give time for combustion, I also enlarge the main draft tube **68** by fashioning a shallow annular bulge indicated at **70**, which defines a chamber **72** within which a second booster flame is generated. For this purpose I provide jets at **74**, fed from a manifold **76** and controlled by a control valve D. The main jet may be located at the downstream end of segregator **66**, but for heavy loads at lower speeds, I prefer to carry the fuel out nearer the center. I have indicated a supply pipe **78** passing through one of the braces **80** supporting the first segregator **64**. The fuel can travel down axially and through one of the second braces **82** supporting the second segregator **66**. From there it may travel down diagonal fuel pipes **84** and discharge in jets indicated at **86**.

The positioning of the jets **86** substantially at the axis makes it possible to use the jets **40** for a much larger fraction of the total power supply, and because these jets have the benefit of the chamber **72**, the combustion in the second booster flame can be made complete and prompt, so that the overall length of the thrust tube necessary to finish combustion may be somewhat reduced.

In operating a power plant with jets according to FIGURE 3, the sequence is generally the same as for FIGURE 2. The operator sets up the flame with control valve A and spark plugs **52**, and then builds a larger flame with control valve B, and then a much larger flame with control valve D. The chief difference is that at cruising speeds the flame in the chamber **72** may still supply approximately the same amount of power as the flame from the jets **86**. Such a multiple stage unit can be made of very large diameter for heavy duty, and still not have so long a thrust tube as to be unwieldy.

Any jet according to the invention may advantageously have its axis curved downwardly from about two to fifteen or twenty degrees just at the base of the receiving cone. Thus, the entering air, while at low velocity at the inlet end, may be directed at a slight downward angle with negligible additional resistance in a horizontal direction, and a comparatively large but still unimportant increment of lift. After the direction has been changed, all the forces of acceleration will operate along the inclined axis and generate a very substantial amount of lift without corresponding loss in thrust. Thus in FIGURE 4, the jet of FIGURE 2 is indicated in side elevation with a short section at **88** curved downwardly and merging immediately with the long straight tube **20**. The segregator **30** is indicated in dotted lines, and the flame in the minor segregated stream is indicated at **90** and the larger flames from the jets **44** at **92**. The jacket **94** encircles the tube **20** throughout the combustion zone and for a considerable distance downstream. The air from the compressor **24** is delivered to the upstream end of the jacket through a suitable pipe **96** and travels downstream to the exit pipe **98**, from which it goes to the manifold **23**. Thus the relatively small initial fuel supply may be materially volatilized by delivering pre-heated air to the manifold **23**.

The cold air in the jacket also materially protects the tube **20** by supplying a substantial cooling effect. In the zone occupied by the flames at **90** and **92** I perforate the tube **20** with perforations of the order of magnitude of ⅛ inch in diameter, arranged in quincunx formation with about one inch between holes. The effective area of these bleed holes is proportioned so that only 10% or 20% of the air delivered by the compressor percolates through into the tube **20**. This cool air tends to build up a layer of relatively cool air devoid of fuel close to the tube wall. Of course, this affords no protection against radiant heat, and at the zone of most intense combustion radiant heat may easily exceed the sensible heat, but the margin of safety afforded by keeping the sensible heat away from tube **20** materially adds to the ability of the structure of the tube to stand up under heavy loads. The mechanical energy used to push air in through the bleed holes is not wasted. It causes an increment in the velocity of the issuing stream.

Where the jet, thus disposed, does not lend itself to

being faired into a wing or other portion of the plane, it may be left naked in the air stream without serious disadvantage, but I prefer to enclose it in a housing diagrammatically indicated at **100**, within which housing there is storage space for fuel or other materials.

Others may readily adapt the invention for use under various conditions of service, by employing one or more of the novel features involved, or equivalents thereof. It will be obvious that the supply pipe **96** can be exposed to the outer air for increased cooling. In large units any booster passage may be subdivided into portions subtending only part of the periphery of the stream. A Pitot tube at the small end of the entrance cone can conveniently operate a bellows for automatically increasing the fuel as a function of the actual air stream available. The axial spacing of the segregators and jets will vary widely with the speed and the types of fuel and atomizing jets employed. A set of rotary blades in the inlet **18** encircling the draft tube **20** near its rear end, would generate a minor fraction of power derived from the power generated in the draft tubes, and this power could be used to actuate the booster **24**.

This application is a continuation-in-part of my copending application Serial Number 158,101, filed April 26, 1950, now abandoned. The conventional diffusers disclosed in the parent case are found to perform no useful function, and have been omitted for that reason.

As at present advised with respect to the apparent scope of my invention, I desire to claim the following subject matter:

1. The method of developing jet thrust for propulsion which comprises: segregating a column of air without material deflection or material radial expansion; further segregating the segregated column into an external annulus and a central core; said external annulus having a cross-section amounting to a minor fraction of the total cross-section; said central core being solid and substantially unobstructed; accelerating the outer annulus rearwardly by extraneous power; deriving said extraneous power from the compression of extraneous air, and also from the burning of fuel in the compressed extraneous air as it enters said segregated fraction in a rearward direction; merging said rearwardly accelerated outer annulus with said central core and permitting the merged entirety to continue substantially without deflection to a point of discharge; said outer annulus being charged with more fuel than it can burn, whereby the merging is accompanied by burning that utilizes some of the oxygen in the central core; said central core, just below the plane of merger, receiving additional fuel for accelerating said core rearwardly by combustion therein; the fuel added to said central core being not in excess of and somewhat less than the oxygen left in said central core can consume before release.

2. The method of developing jet thrust for propulsion which comprises: segregating a stream of air substantially without material deflection or obstruction; further segregating the segregated column into an outer annular fraction and a central core or fraction traveling in parallel paths substantially without defiection; accelerating said outer annular fraction rearwardly by burning combustible fuel in it; merging said rearwardly accelerated outer annular fraction with said central core; burning additional fuel in the merged entirety; and constraining the merged entirety to continue substantially without deflection or enlargement while expansion due to combustion substantially transforms the thermal energy of combustion into kinetic energy.

3. The method of developing jet thrust for propulsion which comprises: segregating a stream of air substantially without material deflection or obstruction; further segregating the segregated column into an outer annular fraction and a central core or fraction traveling in parallel paths substantially without deflection; accelerating said outer annular fraction rearwardly by burning combustible fuel in it; merging said rearwardly accelerated outer annular fraction with said central core; burning additional fuel in the merged entirety; and constraining the merged entirety to continue substantially without deflection while expansion due to combustion substantially transforms the thermal energy of combustion into kinetic energy.

4. In a combustion system for burning fuel in a gaseous stream of combustion-supporting medium; ducting immersed in said stream comprising: a long outer duct; a short inner duct; said inner duct forming the inner wall of a short annular outer passage between said inner and outer ducts; both said ducts being substantially unobstructed from end to end; said short annular passage being adjacent the inlet end of said long duct; independent ancillary power plant means for injecting compressed gas at high rearward velocity into a first zone near the inlet end of said short annular passage; fuel supply means for feeding a flame in said annular passage in a second zone immediately down stream from said first zone; said inner duct and passage merging at their rear ends without abrupt enlargement into a main combustion chamber occupying said long duct; and means adjacent the down stream end of said short duct for injecting additional fuel approximately at the outer periphery of said inner passage, to feed a central flame in said combustion chamber.

5. In a combustion system for burning fuel in a gaseous stream of combustion-supporting medium; ducting immersed in said stream comprising: a long outer duct; a short inner duct; said inner duct forming the inner wall of a short annular outer passage; both said ducts being substantially unobstructed from end to end; said short annular passage being adjacent the inlet end of said long duct; fuel supply means for feeding a flame in said annular passage; said inner duct and passage merging at their rear ends without abrupt enlargement into a main combustion chamber occupying said long duct; and means adjacent the down stream end of said short duct for injecting additional fuel approximately at the outer periphery of said inner passage, to feed a central flame in said combustion chamber.

6. In a combustion system for burning fuel in a gaseous stream of combustion-supporting medium; ducting immersed in said stream comprising: a long outer duct; a short inner duct; said inner duct forming the inner wall of a short annular outer passage; both said ducts being substantially unobstructed from end to end; said short annular passage being adjacent the inlet end of said long duct; fuel supply means for feeding a flame in said annular passage; said inner duct and passage merging at their rear ends without abrupt enlargement into a main combustion chamber occupying said long duct; and means adjacent the down stream end of said short duct for injecting additional fuel to feed a central flame in said combustion chamber.

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