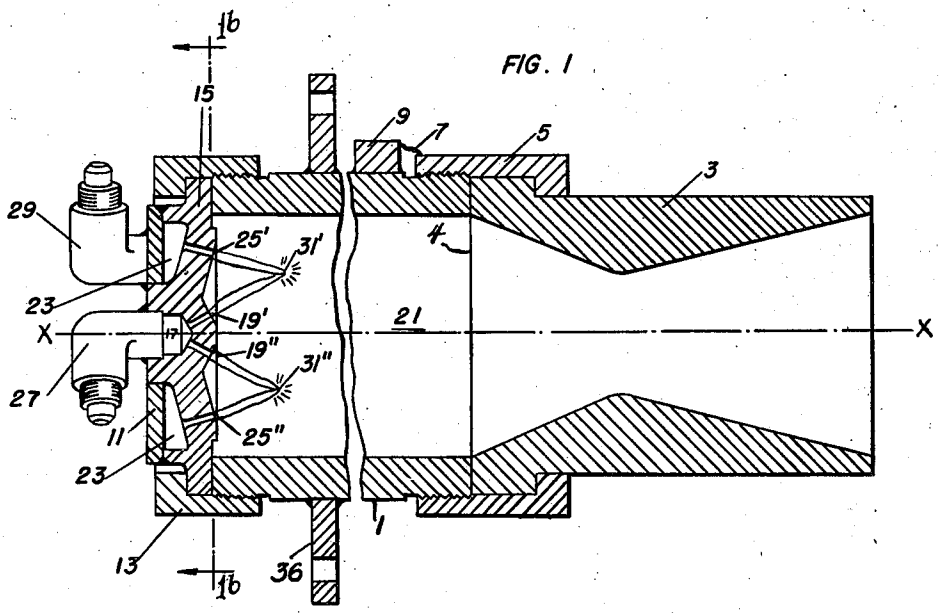
Aug. 6, 1946. M. SUMMERFIELD 2,405,465

JET PROPULSION MOTOR

Filed May 7, 1943

FIG. 1



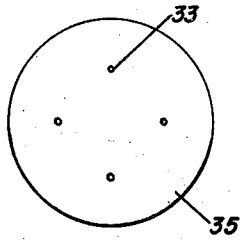


FIG. 2

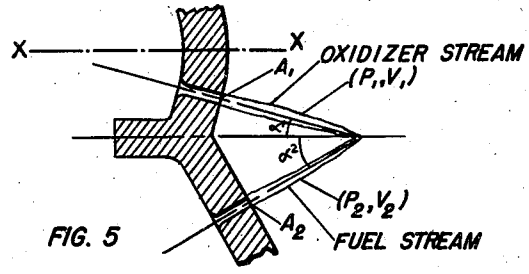


FIG. 5

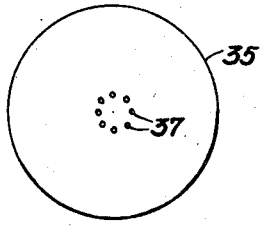


FIG. 3

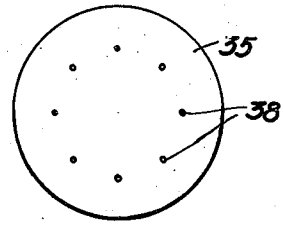


FIG. 4

FIG. 1a

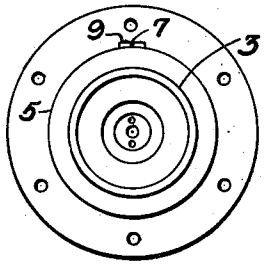
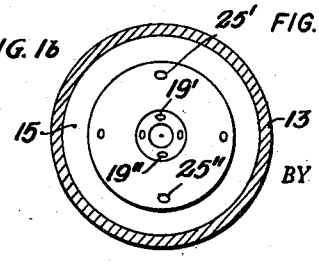


FIG. 1b



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INVENTOR.

BY Fred C. Lawton

AGENT

Patented Aug. 6, 1946

2,405,465

UNITED STATES PATENT OFFICE

2,405,465

JET PROPULSION MOTOR

Martin Summerfield, Pasadena, Calif., assignor to Aerojet Engineering Corporation, Azusa, Calif., a corporation of Delaware

Application May 7, 1943, Serial No. 486,078

2 Claims. (Cl. 60—35.6)

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This invention relates to jet propulsion and particularly to means and methods for increasing combustion efficiency of jet propulsion motors.

A jet propulsion motor of the type to which my invention is particularly applicable comprises a tubular (substantially cylindrical) body having an exhaust nozzle at one end and means for introducing liquid propellants through injector orifices as separate streams into the other end. The space within the tubular member between the injector and the nozzle throat serves as a combustion chamber. The propellants are spontaneously combustible.

The present invention contemplates the use of an injector at the end of the motor body opposite the nozzle and has particular reference to the arrangement of the motor parts and more particularly to the propellant fluid injector orifices and their arrangement with respect to the combustion chamber. Jet propulsion motors constructed according to my invention provided maximum combustion efficiency compatible with the nature of the propellants used and the mixture ratio required and hence provide maximum thrust per unit weight compatible with the conditions of operation under which the motor is to be used which conditions may be specified for example with respect to thrust, or operating time to reach a certain temperature. I have found that the combustion efficiency of such a motor can be made very nearly 100 percent, and that other desirable results can be obtained by constructing and operating the motor according to the following principles.

1. The length of the motor from the injector at one end and the nozzle throat at the other end should be between about one and three times the inside diameter of the motor;

2. The combustion volume of the motor should be greater than 25×area of throat (all units in inches) and preferably less than 200, when using aniline and nitric acid at combustion pressures between 100 and 600 p. s. i. All of these conditions apply particularly to aniline and nitric acid. However, it is to be understood that I do not intened to be limited to the exact figures stated above and that for other propellants, other numerical values may be more suitable;

3. The propellants should be injected into the motor as a plurality of pairs of streams having individual impingement points;

4. Such impingement points should be distributed substantially uniformly over the cross

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sectional area of the motor in front of the injector;

5. The angle included between the propellant streams should be greater than about 30°;

6. The points of stream impingement should be spaced at least about ¼" away from the wall of the injector;

7. The stream velocity should be at least 50 feet per second;

8. The two fluid propellants should be injected into the jet propulsion motor as separate streams under such conditions that the streams of the propellants will impinge and the momentum of the resultant propellant mixture will be substantially parallel to the motor axis.

By injecting propellants into the motor as a plurality of pairs of streams and distributing the points of impingement substantially uniformly throughout the cross sectional area of the combustion chamber the initial flame area is distributed more uniformly over the motor area. This gives an optimum distribution of propellants and hence increases combustion efficiency. By injecting them at the end remote from the nozzle the components of the propellant mixture have an opportunity to burn for a long time as they flow under the influence of combustion energy from the injector end to the nozzle end.

These and other features of my invention may be more readily understood by reference to the accompanying description taken in conjunction with the drawing in which

Fig. 1 is a cross sectional view of a jet propulsion motor incorporating my invention;

Fig. 1*a* is an end view of Fig. 1.

Fig. 1*b* is an elevation view of the orifice plate taken in section at line 1*b*—1*b* of Fig. 1;

Fig. 2 is a diagram showing a distribution of impingement points over the combustion chamber cross sectional area, which I have found to be highly satisfactory;

Figs. 3 and 4 are diagrams representing arrangements of eight impingement points, over the same area; and

Fig. 5 is a schematic diagram used in explaining my invention.

In Fig. 1 I have shown a jet propulsion motor having a tubular section 1 to one end of which a nozzle 3 is secured by means of a collar 5 and a safety wire 7 connecting the collar to a safety wire lug 9 welded to the extension wall of the tubular section on the outside thereof. At the other end of the tubular body there is secured an injector 11 by means of a collar 13.

Said injector comprises an orifice plate 15 and an injector back plate 11. In the orifice plate there is a central recess forming a central manifold 17 which is connected by a first set of ports 19', 19'' to combustion chamber 21 in the interior of the motor. An annular recess forms a second manifold 23 which is connected to the combustion chamber through a second set of orifices 25', 25''. The manifolds 17 and 23 may be connected to corresponding liquid propellant supplies through the corresponding elbow connectors 27 and 29. A mounting ring 36 concentric with and secured to the tubular section is provided for mounting the motor on an aircraft.

It is desirable in the operation of jet propulsion motors to supply propellants to the motor at predetermined rates and in predetermined proportions. These rates may be desirable either to operate the motor at maximum thrust or at a temperature suitable for giving a sufficiently longer operating period to a motor of a predetermined thrust. The specific requirements depend on the use to which the motor is to be put.

Means may be accordingly provided for supplying a fuel through the ebow connector 27 into the central manifold 17 and thence to the combustion chamber 21 through the orifices 19' and 19'' at predetermined rate and velocity. Means may also be provided for supplying an oxidizing agent to the annular manifold 23 through the elbow connector 29 and thence to the combustion chamber 21 through orifices 25' and 25''. Each pair of orifices 19', 25' and 19'', 25'' respectively direct the fuel and the oxidizer toward corresponding points 31' and 31'' of impingement. A system for controlling the flow of propellants is described in detail in my copending patent application Serial No. 486,077, now abandoned. It can be shown that if the cross sectional areas of the orifices carrying oxidizer and fuel respectively are A_1 and A_2 respectively and the corresponding densities and velocities of the propellants streaming therethrough are P_1V_1, and P_2V_2 respectively it can be shown that if the following relation holds

$$P_1A_1V_1^2 \sin \alpha_1 = P_2A_2V_2^2 \sin \alpha_2 \quad (1)$$

where α_1 and α_2 are the angles that the respective streams form with the longitudinal axis X—X of the motor, then the resulting momentum of the propellant mixture after impingement will be parallel to the motor axis. Equation 1 means that the forces exerted by the two propellant streams impinging at each impingement point 31' and 31'' are equal and opposite. Expressed in still another way the transverse components of the momentum (that is the components perpendicular to the motor axis) carried by the separate streams per sec. to the respective points of impingement are equal and opposite. When the resultant momenum is substantially parallel to the motor axis, the propellant mixture, which is dispersed as a result of the collision of the two streams, distributes itself substantially uniformly over the cross sectional area of the motor and very little of it strikes the wall there to condense and flow out the nozzle as unburned propellant. Because of this fact more of the propellants are subjected to combustion under optimum combustion conditions, thereby resulting in high combustion efficiency.

In order to produce fine dispersion of the propellant mixture by virtue of the mutual impingement of the streams I utilize stream velocity greater than about 50 feet/second and cause

the streams to impinge at a large angle, preferably greater than about 30°. However, the magnitude of the impingement angle is limited by the fact that overheating of the injector due to convection, conduction, and radiation of heat from the flame will occur, if the impingement points are closer than about ¼'' from the wall of the injector.

In order to further distribute the propellants over the cross sectional area of the motor I space the orifices on the injector in such a way that the point of impingement will be substantially uniformly spaced over the cross sectional area of the motor. Thus for example in Fig. 2 I have shown diagrammatically how four impingement points 33 may be distributed over the cross sectional area of the combustion chamber, the outline of which is here represented by the circle 35. In this arrangement the four impingement points are symmetrically spaced over the cross sectional area and at the corners of a square having a diagonal approximately equal to the radius of the cross sectional area. Similar arrangements may be readily applied when any arbitrarily selected number of impingement points are utilized.

Figs. 3 and 4 show two possible arrangements of 8 impingement points. In Fig. 3 the impingement points 37 are closely spaced and at the center of the combustion chamber, and in Fig. 4 the impingement points 38 are spaced uniformly on a circle having its center on the axis of the cross sectional area and this circle has a radius about half that of the cross sectional area. While more uniform distribution of the propellant mixture could be obtained by spacing every other one of these impingement points closer to the wall of the motor chamber and the remaining impingement points closer to the center of the chamber I have found it far simpler to space the impingement points uniformly on a circle as shown on Fig. 4 as this facilitates manufacture of the injector. The arrangement of Fig. 4 gives greater combustion efficiency than that of Fig. 3. Both the arrangement of Figs. 2 and 4 have proved highly satisfactory in practice.

When the number of impingement points is small (less than about 12) they are preferably spaced from the combustion chamber between a pair of circles centered on the axis X—X and having radii between about one fourth and three fourths the radius of the combustion chamber. When more than twelve impingement points are used they are preferably arranged over a wider area so as to distribute them substantially uniformly throughout the cross sectional area of the motor.

Equation 1 above only specifies a relationship between α_1 and α_2 if the values of P_1, P_2, A_1, A_2, V_1, and V_2 are known. The relationship between the values is determined by the ratio of the pressure drops across the orifices and the required proportions of the propellant mixture. In order to reduce the amount of gas pressure required to drive the propellant into the combustion chamber I utilize orifices which are rounded on the high pressure side, the radius of the round section preferably being between about one fourth and twice the diameter of the respective orifices. In this manner the drops in pressure through the orifices are kept small and the loss of pressure energy supplied by the gas pressure drive means is kept small. This feature also assists in maintaining a high com-

bustion efficiency. By combining the various principles hereinbefore set forth I am able to achieve high combustion efficiency in jet propulsion motors.

I have observed that the efficiency of combustion is also affected by the relative directions of the momenta of the individual propellant mixtures formed at the various stream impingement points, and that the combustion may be substantially completed in a shorter distance when when the lines of average momentum of such mixtures do not intersect each other in the space between the injection points and the entrance to the nozzle. The momenta of the separate streams are preferably directed to points in the area at the nozzle entrance on the same side of the motor axis as the respective impingement points. The maximum efficiency of combustion is obtained when these lines of momenta are substantially parallel to each other, and to the motor axis, and the impingement points are distributed substantially evenly over the cross-sectional area of the motor.

I claim:

1. In a jet propulsion motor comprising a tubular body section, an exhaust nozzle at one end of the tubular body and a propellant injector at the other end of the tubular body, there being a longitudinal axis extending centrally through the body and centrally through the exhaust nozzle, said body, injector and exhaust nozzle forming a combustion chamber, the improvement which comprises a plurality of pairs of propellant injection orifices through the injector, means for supplying a propellant fluid to one orifice of each pair, and means for supplying a different propellant fluid to the other orifice of each pair, the orifices of each pair being directed so that their axes extend in the general direction of said longitudinal axis and intersect at a point within the chamber, whereby the propellant fluids passing through the orifices of each pair impinge at said point, the positioning of said orifices and the

arrangement being such that the product of fluid density, stream cross-sectional area, the square of stream velocity and the sine of the angle between the axis of the fluid stream and the longitudinal axis of the nozzle for one fluid stream equals that for the other stream whereby the direction of motion of the propellant fluids after impingement is substantially parallel with said lonigtudinal axis, the impingement points being substantially uniformly spaced over the cross-sectional area of the combustion chamber.

2. In a jet propulsion motor comprising a tubular chamber having at one end an exhaust nozzle and at the opposite end a fluid injection plate, means for introducing into the tubular chamber a plurality of propellant fluids, said means comprising a plurality of injection holes through the injection plate and arranged in a circle symmetrically around the longitudinal axis of the tube, and a second set of holes arranged in a circle of larger diameter than the first-mentioned circle, the axis of each hole of the first-mentioned circle being directed to meet the axis of an individual hole of the second-mentioned circle at a point of impingement within the chamber, said points of impingement being arranged in a circle within the chamber which has a diameter intermediate between that of the first-mentioned circle and that of the second-mentioned circle, and means for supplying one propellant fluid through the first set of holes and another propellant fluid through the second set of holes, the arrangement being such that the product of fluid density, stream cross-sectional area, the square of stream velocity, and the sine of the angle between the axis of the fluid stream and the longitudinal axis of the nozzle for one propellant fluid substantially equals that of the other propellant fluid, whereby the resultant momentum of the propellant mixture after impingement is substantially parallel to said longitudinal axis.

MARTIN SUMMERFIELD.