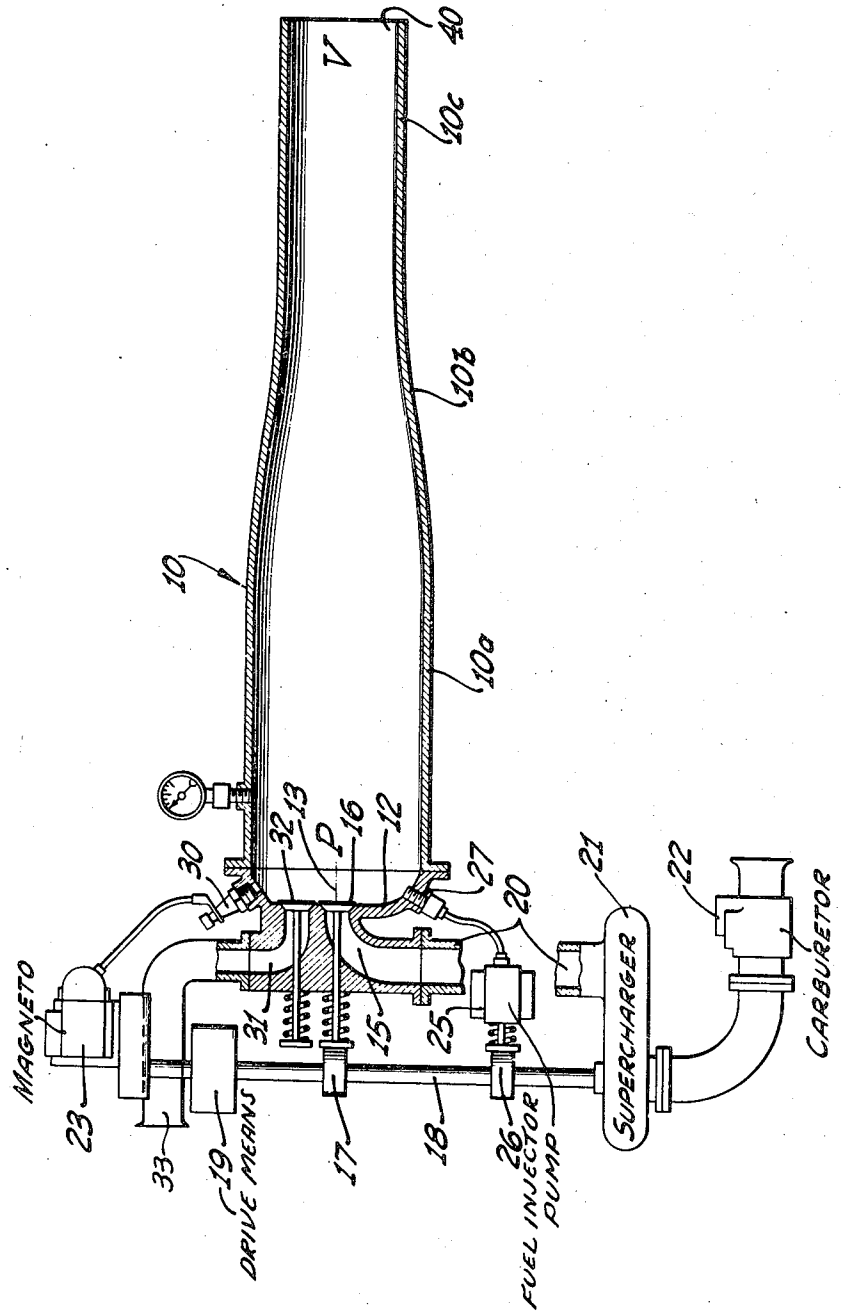
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RESONANT PULSE JET ENGINE WITH TAPERED PIPE

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RESONANT PULSE JET ENGINE WITH TAPERED PIPE

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3 Claims. (Cl. 60—35.6)

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This invention relates generally to jet propulsion engines, and more particularly to jet propulsion engines of the resonant pulse jet type.

The present application is a division of my parent application Serial No. 439,926 (now abandoned), filed April 21, 1942, to which reference is here made.

Pulse jet engines of the class to which the present invention is directed employ a tubular housing having a closed end portion that houses a fuel combustion zone, and a discharge orifice at the opposite end through which gaseous products of combustion, and sometimes auxiliary air, are discharged. Fuel combustion is effected intermittently, at a resonant frequency of the quarter-wave pipe formed by the tubular housing, so that a standing wave is established in the fluid column contained in the pipe, with a pressure anti-node at the combustion zone and a velocity anti-node at the open end. This standing wave governs the operating cycle of the apparatus, and is of the utmost importance to its favorable behavior, all as fully explained in my said application Serial No. 439,926.

A general object of the invention is the provision of an improved form of tubular resonant housing leading to operation at increased over-all efficiency, higher "Q," and to improvement of fuel combustion, including both more rapid and efficient burning of the fuel mixture, and the creation of conditions favorable to a type of self-ignition.

These objects are realized in the apparatus of the invention by the provision of a tubular housing which may be generally described as bottle-shaped in nature. More particularly described, the tubular housing is of relatively large cross-section at its closed end, and is provided at a region intermediate its ends with a tapering constriction, beyond which is a reduced portion leading to the discharge orifice at the tail. Such a constriction reduces the resonant frequency of the fluid column, thus giving a shorter pipe for a given resonant frequency. With the shorter pipe, frictional losses at the wall surfaces are reduced, and the operation becomes characterized by higher "Q," "Q" being understood to represent the ratio of energy stored to energy dissipated per half cycle, and being a factor which in a general way denotes the "fly-wheel effect" of the standing wave system.

Other advantages and characteristics resulting from the described "bottle-shaping" of the resonant housing or pipe will be reserved for discussion in connection with the following detailed description of an illustrative embodiment of the

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invention, wherein reference is had to the single figure of the drawing showing a longitudinal sectional view, partly in elevation, of an illustrative embodiment of the invention.

The reference numeral 10 designates generally the tubular resonant housing or pipe of the apparatus, the head end of which is conventionally shown to have head or closure 12. Provisions are made for creating successive pressure pulses in the zone 13 adjacent to this head, and these provisions may be any of those disclosed in my aforesaid application Serial No. 439,926, or such as disclosed in my subsequent application entitled Method and apparatus for jet propulsion, Serial No. 521,575 (now abandoned), filed February 8, 1944, or any other found suitable. I have shown for the purpose of illustration a fuel combustion means like that of Figure 6 of my application Serial No. 439,926, the head 12 having for the purpose fuel intake passage 15 opening therethrough, which passage is controlled by a suitable poppet valve 16 operated by a cam 17 on cam shaft 18. The latter may be driven by any speed-governed drive means, such as an electric motor, internal combustion engine, turbine, etc., the drive means being conventionally indicated in the drawings at 19. Coupled to intake passage 15 is a supply pipe 20 to which the mixture is fed from supercharger 21, the mixture being formed by a suitable carburetor 22. Cam shaft 18 may also drive the supercharger, as well as a magneto 23. As an alternative or supplementary fuel supply means, there may be provided a supplementary fuel injector pump 25 driven from cam 26 on cam shaft 18 and acting to meter a liquid fuel directly into the combustion chamber 13 via injector nozzle 27. The magneto and cams on shaft 18 are, of course, arranged to provide the desired timing of fuel introduction and ignition (as by use of spark plug 30 connected to magneto 23).

Head 12 is also shown as provided with an auxiliary air intake passage 31, controlled by spring-closed intake valve 32, this air intake passage being understood to be supplied with air from any desired source, which may be of conventional character, such as a forwardly facing air scoop 33 or the like.

The tubular housing or pipe 10 may be generally described as bottle-shaped, having a closed, head end or body portion 10*a*, a tapering or converging intermediate portion 10*b*, and a reduced neck portion 10*c* terminating in discharge orifice 40.

Operation is as follows: Charges of fuel and air mixture are intermittently introduced to chamber 13 via cam operated intake valve 16.

Combustion may be initiated by spark plug 30, which then explodes the fuel and air charge in chamber 13. Each such fuel explosion creates a positive pressure pulse, which starts a wave of compression travelling the length of pipe 10 with the speed of sound. Reaching the open end of the pipe, this wave is expanded, and reflected by inverse reflection as a wave of rarefaction returning up the pipe. The wave of rarefaction is reflected by the head 12 as a wave of rarefaction travelling back down the pipe, and when the open end of the pipe is reached, inverse reflection again occurs, returning a wave of compression back up the pipe to create a positive pressure in the head end region 13.

In the meantime, valve 16 has admitted a further fuel charge, and the timing is preferably such that this occurs during the portion of the described cycle that a rarefaction prevails in zone 13, so that fuel introduction is facilitated. The pressure depression will also result in automatic opening of check valve 32, and consequent introduction of auxiliary air.

The described wave of compression travelling up the pipe compresses this fuel charge in zone 13; and the timing of magneto 23 is such as to create a spark at plug 30 as the positive pressure peak of the returning wave is being reached. The result of the explosion is an augmented positive pressure peak, which thereupon initiates an augmented pressure cycle of the type just described.

The result of the described wave activity in the gas column is a standing wave, with a velocity anti-node V at the open end of the pipe, and a pressure anti-node P at the closed end thereof. It is the described resonant timing of the fuel valve 16 and spark plug to the natural fundamental frequency of the pipe, i. e., introducing the new fuel charge at the proper time in the cycle, and causing the explosion to occur as the positive pressure peak is reached, that creates and sustains this desired standing wave. Products of combustion, together with auxiliary air, progress down the pipe and are discharged from the orifice 40 as a propulsive jet.

The immediately preceding description of operation applies whether or not the bottle-shaped housing is employed. The operation is favorably modified by the use of the bottle-shape in the following respects:

First, the convergence contracts the "front" of the wave travelling down the pipe, which results in a shortened length of pipe for a given operating frequency. This is of advantage, not only for reasons of compactness, but because a shortened pipe has less wall surface, and hence less losses owing to friction between the gas column and the wall surfaces of the pipe. Lessened losses mean increased "Q," and therefore a stronger standing wave. The importance of any degree of improvement in the standing wave follows from the fact that the standing wave is the flywheel of the wave system, controls and stabilizes the events of the operating cycle, and determines the efficiency and power of the apparatus.

Another advantage of the bottle-shaped housing resides in the obtainment of augmented pressures in the combustion region 13 because of the mass reactance effect of the tapered neck. These increased pressures result in more rapid and efficient burning of the combustible fuel mixture.

A still further advantage of the bottle-shaped formation is that its provision may dispense with the necessity of electric ignition, except for starting. Once the combustion cycle has been established, and operating temperatures established, an annular outer ring of flame tends to be maintained at the walls of the pipe around the combustion zone 13. The flame within this region appears to be somewhat protected by the shoulder afforded by the bottle-shaped formation, and while the flame is considerably attenuated during the negative half of the cycle, it is not completely extinguished, and serves as a self-ignition source on the positive pressure portion of the cycle.

I claim:

1. A jet propulsion apparatus which includes: a fluid filled pipe having a closure providing a wave reflector at one end and a fluid opening providing wave expansion at the other end and said pipe having inwardly tapering walls toward said open end to provide wave contraction between said reflector and said wave expansion, said fluid filled pipe being adapted to resonate with a standing wave created in said fluid having a pressure anti-node near said one end and a velocity anti-node near said other end, and means for generating pressure pulses in the fluid in said conduit at the resonant frequency for said pipe to establish and maintain said standing wave and cause fluid to be propelled through said fluid opening in response to fluid pressure variations of said standing wave.

2. A jet propulsion apparatus which includes: a housing defining and containing a column of fluid adapted to have a standing wave established therein, pressure wave reflecting means at one end of said column, there being a fluid discharge opening located at the other end of said column through which fluids may be propelled by pressure changes developed by said standing wave, and said housing having a constriction intermediate the ends of said column, pressure disturbance means in pressure transmitting relationship with said fluid column operative at a resonant frequency of said fluid column to establish a resonant standing wave therein, said reflecting means establishing a pressure anti-node of said standing wave adjacent said one end of said fluid column, said fluid opening establishing a pressure anti-node of said standing wave substantially nearer to said other end of said column than to said one end, and said housing constriction reducing the resonant frequency of the fluid column as compared with a pipe of similar length but of uniform cross-section.

3. A jet propulsion apparatus which includes: a fluid filled housing defining a fluid column and consisting of a pipe closed at one end and open at the other with a convergence at an intermediate region so arranged as to reduce the cross-sectional area of the open end of the pipe, means for intermittently creating pressure pulses in the closed end of the pipe, at a resonant frequency, and means for introducing fuel charges and air to the closed end portion of the pipe for intermittent explosion therein at the resonant frequency of the pipe, whereby a standing wave is created in the fluid in the pipe, with a pressure anti-node adjacent the closed end thereof and a velocity anti-node at the open end thereof, and whereby products of combustion move down the pipe and are discharged from the open end of said pipe.

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No references cited.