June 7, 1955 J. Y. DUNBAR ET AL 2,709,891

VALVELESS RESONATING JET MOTOR

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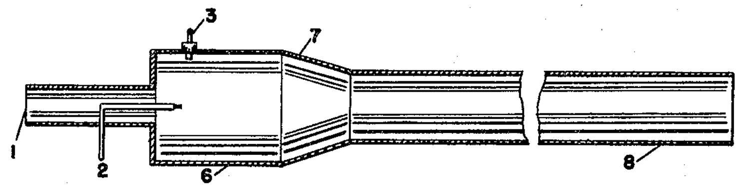

FIG. 1

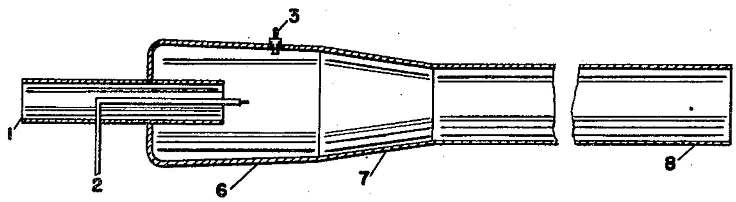

FIG. 2

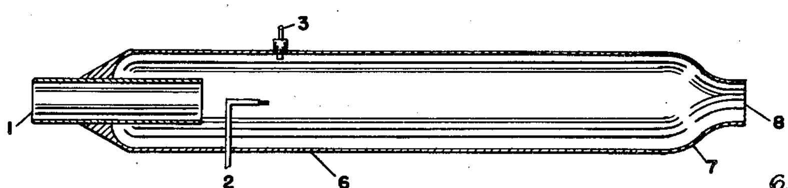

FIG. 3

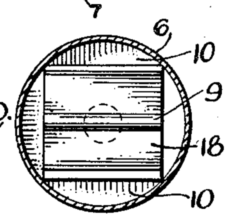

FIG. 10.

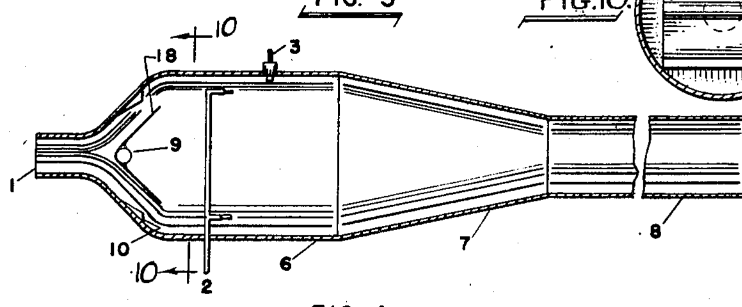

FIG. 4

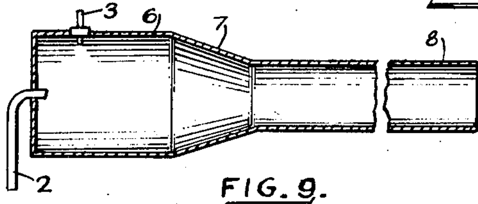

FIG. 9.

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VALVELESS RESONATING JET MOTOR

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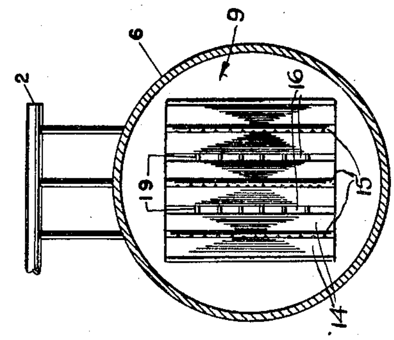

FIG. 8

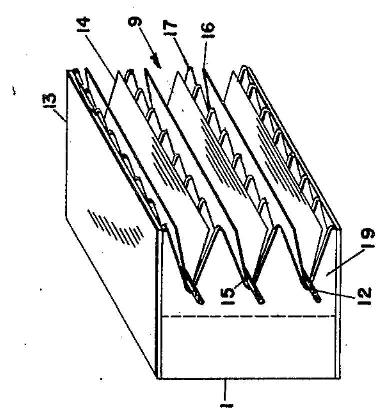

FIG. 7

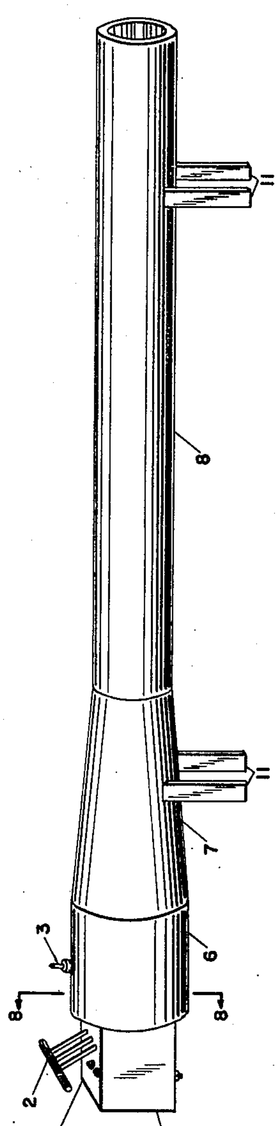

FIG. 5

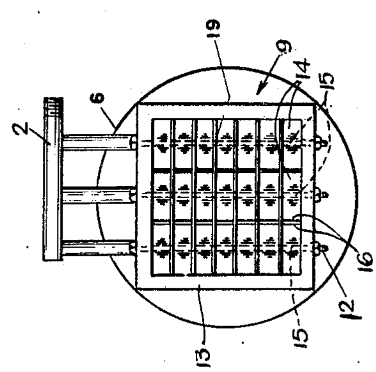

FIG. 6

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VALVELESS RESONATING JET MOTOR

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2 Claims. (Cl. 60—35.6)

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This invention relates to a resonant jet engine and has for its object to provide an internal combustion engine which fires at a cyclic rate wherein the power is derived directly from the jet reaction due to acceleration of gas discharged at each explosion. Another object of the invention is to provide a source of power adapted to drive an impeller as the jet may be directed against vanes of a rotor. A further object of the invention is to provide an internal combustion engine wherein the cyclic rate of explosion is approximately in resonance with the natural frequency of the engine. Another object of the invention is to provide a cyclically operative internal combustion engine or motor which does not require any system of valves, mechanically driven or otherwise, to control the flow of air or other fluid supporting combustion. A further object of the invention is to provide an engine which does not require a cyclically operative system of valves to control the flow of fuel. An additional object is to furnish a motor adapted to operate with a fuel which incorporates its own oxygen to support combustion either admixed or compounded therein, such as nitrogen-oxygen compounds of hydro-carbons hereinafter termed propellant compound. A further object is to provide a jet engine and vibrating valve system therefor wherein the rate of explosion of the engine is at a somewhat lower rate than the natural rate of operation of the valve system therefor and wherein resilient valves are restrained from vibration solely by the pulsating flow of gases incident to operation of the motor. Another object of the invention is to provide an engine which is light in weight and simple to manufacture.

Further objects of the invention will appear from the description and drawings, wherein:

Figure 1 is a diagrammatic view of an engine built according to the invention;

Figures 2, 3 and 4 are diagrammatic views of different modifications of the engine;

Figure 5 is a view of the engine illustrated in Figure 4, and including a modification of a valve;

Figure 6 is an end view of the air intake of Figure 5 looking toward the motor;

Figure 7 is a perspective view of the valve of Figure 6, rotated through ninety degrees;

Figure 8 is a sectional view along line 8—8, Figure 5;

Fig. 9 is a cross-sectional view of yet another modification of the invention; and

Fig. 10 is a sectional view along line 10—10, Fig. 4.

Reference is made to the drawings wherein like numerals refer to like parts. The air to support combustion enters the combustion chamber 6 through the air port 1, the chamber is provided with an inlet 2 for the volatile fluid fuel, a conventional spark plug 3 and a nozzle pipe 8 connected by means of a nozzle cone 7. The unit is supported by any convenient means such as the supports 11.

The nozzle pipe 8 is unobstructed to assure free discharge of gases of combustion. Fluid supporting combustion, hereinafter termed combustion air, may be admitted without valve control. These species are shown

in Figures 1, 2 and 3. Figures 4 and 5 illustrate species provided with valves. As shown in Figures 4 and 10 each valve 9 may be a flat sheet of resilient material attached along one edge of the body adjacent an opening 18 and extended downstream to overlap the opening. The combustion chamber is formed to provide a seat at 10. As illustrated in Figures 4 and 10 each valve is set to overlie the opening at all times except when forced to open under suction. Normally each valve is held closed by its own resilience and the force of an explosion. The valve utilized in the species illustrated in Figure 5 is illustrated in Figures 6, 7 and 8. In this species the opening is formed of such a configuration 13 immediately adjacent the point it joins the chamber 6 as to receive valve mechanism therein. The configuration is illustrated as rectangular but this is not material. The mechanism consists of a series of resilient plates 14. These plates are all generally rectangular and are attached along one edge at 15. The mounting edge 15 and free edges 16 are all parallel. In order to make certain that the valve mechanism 9 may open very rapidly the attachments at 15 of all the plates are in the same plane and, means in the form of horizontal baffle plates 19 project from the plane of the mounts in the direction of flow of combustion air and limit the swing of plates 14 in the closing direction. This edge of each baffle is in the form of a series of saw teeth or points 17. The edge of each point measured from its base to the tip 17 is substantially the same length as the width of a plate 14, so that the free edges of these plates meet along lines in a plane spaced from the hinge edges 15, and the valve means 9 in closed position consists of a series of acute dihedral angles.

Tests demonstrate that starting the engine requires a supply of combustion air. This air supply may be obtained by relatively rapid movement of the surrounding air such as would be produced by mounting the unit on an aircraft or in a wind tunnel, or it might be obtained from a blower temporarily discharging into the inlet 1. This means of supply air is not a part of the invention. Operating tests demonstrate that upon starting the species of the device equipped with valves, mechanical provision of air may be discontinued and the motor will continue to draw in sufficient air for each explosion due to the partial vacuum resulting from the preceding explosion. The use of an outside source of air is recommended for the species shown in Figures 1, 2 and 3.

In all forms the cyclic operation consists of building up the pressure in chamber 6 during the explosion, ejecting the gases of combustion through the tail pipe 8 thus creating thrust by jet reaction, the escaping gases creating a partial vacuum within the chamber 6 which draws in a new charge of air through the inlet tube 1 and valves 9, then repeating the explosion.

In the valveless type it is noted that the tail pipe 8 is so proportioned with respect to the inlet 1 that the explosion has the dual function of first impeding all flow of air through 1 into the chamber 6 and thereafter ejecting gases through the exhaust pipe 8 with such violence as to create by inertia effect a partial vacuum in chamber 6, thus pulling in a new charge of combustion air through 1 into the chamber 6. The preferred dimensions of pipe 8 in this form as indicated above are therefore such that will give the combustion chamber and tail pipe combination substantially the same natural acoustic frequency as that of the inlet 1 under operating temperature and pressure conditions. Thus the natural impedance of the inlet may be made sufficient to reduce to a minimum the reverse flow in the inlet during explosion in the combustion chamber.

In all of the valve type models the force of the explosion closes the resilient mechanical valves, and when the partial vacuum is produced in the chamber these valves are opened by the pressure differential and a new flow of air into chamber 6 takes place.

In all cases and in all types where propellant compound, carrying its own oxygen, is utilized no other material need be provided the engine from any other source and, therefore, the valving means (intake tube 1 and valves 9) for atmospheric air may be removed as shown for example in Fig. 9.

The electric power necessary to provide the spark may be furnished by a conventional spark coil. During test the spark was discontinued within one half a second after starting and the motor continued to function. The continued firing was obviously supplied by the residual hot gases from the previous explosions. Therefore, an ignition system is not essential to the operation of the engine and is not of itself part of the invention. The portion of the back wall adjacent the inlet tube provides an eddy current and flame-maintaining area, for firing succeeding charges after the first.

Having described the mechanical elements constituting the engine according to the invention it is apparent that the rate of firing, or the frequency of successive explosions, is not controlled by mechanically driven moving mechanical parts such as push rods for the valves or spark timing gear in the ignition in the manner of conventional internal combustion engines. As the engines actually operate with a series of individual explosions in close sequence recurring at substantially uniform time intervals which is termed herein "cyclic rate" a statement of the design feature determining this operation is considered essential to an understanding of the invention.

A fundamental law of physics is that a jet of gas projected across the open end of a pipe which is closed at the other end will produce vibrations having a fundamental wave length Y which is four times the length of the pipe and the frequency F of these vibrations per second is equal to the velocity, in feet per second, of sound in the fluid medium in the pipe divided by the length Y of each wave—that is

$$F=\frac{V}{Y}$$

As the velocity V of sound in a gas varies with the temperature of that gas a correction factor based on temperature must be included. The engine disclosed in Figure 5 is such a pipe and test has demonstrated that the valveless form illustrated in Figure 1 operates in like manner. Taking the length from the front end of the firing chamber to the rear end of tube as L the design frequency of a unit may be determined in advance.

The valves shown are of a resilient sheet metal type of such mass and stiffness as to follow the pressure differenials created by the cyclic operation of the engine. They are capable of being opened by the partial vacuum created after the explosion and are closed by the stored energy in their distorted open position and the force of explosion.

The motor according to this invention may be utilized in many associations and among these the specie illustrated in Figures 1, 2 and 3 is particularly well adapted for installation in locations where high velocity currents of air may flow toward the inlet. It has been found that the power of all species is increased in this latter association and those species wherein valves are omitted such as illustrated in Figures 1, 2 and 3 are particularly responsive to the air supply.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What we claim is:

1. Apparatus of the character described, which includes: a resonant fluid housing forming an acoustic cavity for a standing wave and a continuously open conduit for a fluid stream, said housing having a fluid discharge opening which locates a velocity anti-node of said standing wave thereadjacent, said housing also enclosing a pressure anti-node region of said standing wave, means for introducing fuel to said pressure anti-node region, and a continuously open air intake conduit opening into said housing at a junction point in the general region of said pressure anti-node, said air intake conduit having at its junction with said housing an acoustic impedance for the frequency of the standing wave in said resonant housing which is substantially as high as the acoustic impedance of the resonant housing at said point of junction for said frequency.

2. An acoustic jet engine which includes: a resonant acoustic standing wave cavity forming a continuously open conduit for a fluid stream, a jet discharge opening leading from said conduit, said conduit having velocity anti-node and pressure anti-node regions upstream from said jet discharge opening, and a velocity anti-node region at said jet discharge opening, fuel introduction means discharging to said pressure anti-node for maintaining periodic combustion to provide periodic pressure pulses for wave generation at said pressure anti-node at a resonant frequency of said cavity, and air introduction means consisting of an air intake opening continuously into said conduit at the velocity anti-node region upstream from said pressure anti-node region of said conduit.

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