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RESONANT PULSE JET DEVICE WITH RESTRICTED FLOW PASSAGE

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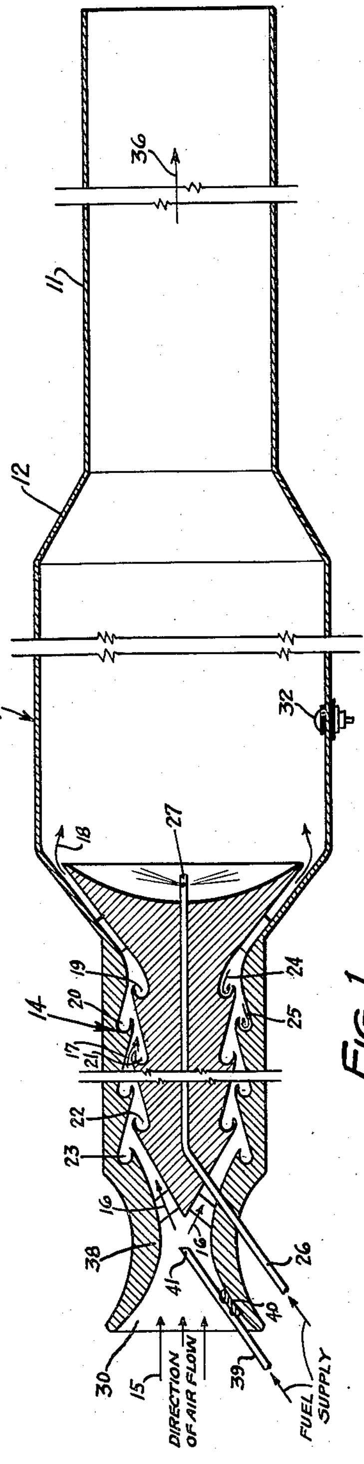

FIG. 1

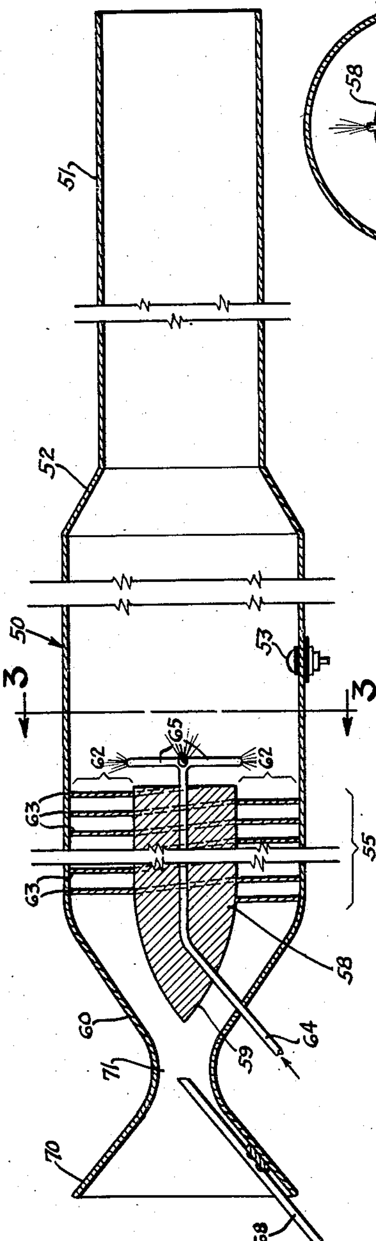

FIG. 2

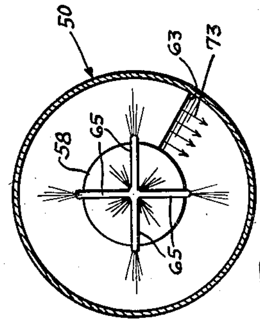

FIG. 3

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RESONANT PULSE JET DEVICE WITH RESTRICTED FLOW PASSAGE

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5 Claims. (Cl. 60—35.6)

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This invention relates to pulse jets of the valveless or ram air type wherein the air or fuel-air mixture for combustion is introduced into the combustion chamber and therein exploded and expelled, through the tail pipe or pipes of the jet, cyclically. The combustion chamber thus has an inlet pipe and an outlet pipe by way of the tail pipe or pipes through either of which the combustion gases might pass, except for the provision of valves as have heretofore been employed or through the action of ram air which, according to some theories of operation, heads the discharge of the explosion gases in an appropriate direction out of the exhaust pipes.

It is an object of the present invention to provide an improved structure wherein no valves are required and in which the operation may be sustained with no ram air or with lesser ram air pressure than heretofore required.

Other and further objects of the invention are those inherent in the apparatus herein illustrated, described and claimed.

The invention is illustrated with reference to the drawing in which:

Figure 1 is a longitudinal sectional view of the apparatus of the present invention;

Figure 2 is a longitudinal sectional view of a second form of the invention;

Figure 3 is a transverse sectional view taken in the direction of arrows 3—3 of Figure 2.

Throughout the drawing corresponding numerals refer to the same parts.

Referring to the drawing (Fig. 1) the pulse jet device includes a combustion chamber 10 of suitable length and diameter connected to one or more tail pipes 11 of suitable length and diameter through, usually, a reducing section 12. In accordance with the present invention the introduction of air or air-fuel mixture into the combustion chamber 10 is through a labyrinth network 14 having a shape and configuration such that the flow of gases in the direction of air flow, indicated by arrows 15, 16, 17 and 18, is accomplished with a relatively lesser resistance to air flow than a flow in the opposite direction. Many types of labyrinth may be utilized for this purpose, of which two are illustrated in Figures 1 and 2 of the drawing. It will be seen that the inlet passage is arranged in a generally annular shape and preferably opens into the combustion chamber at a substantial angle to the axis thereof, the solid body inwardly of the passage opening forming a baffle at the end of the chamber adjacent the inlet passage for reducing reverse flow of gases

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through the inlet passage under the resonating operation.

In Figure 1 the labyrinth type passage is formed between the outer wall of the unit and the inner core which is suitably supported on longitudinal webs. It is provided with shaped pockets 19, 20, 21, 22 and 23 which are in reality annular chambers around section 14. The pockets 19–23 are of toroidal shape and the air passage through each such toroidal pocket is in a direction such that reverse air flow causes a rapid whirling action, as indicated by the arrow 24 in the pocket 19 and the arrow 25 in the pocket 20. Thus, reverse flow causes an intense whirling action, and the resulting multiple vortices in pockets 19–23 establish an immensely greater resistance to air flow from the combustion chamber to the entrance horn 30 than from entrance horn 30 into the combustion chamber. In this way when the air fuel mixture is ignited in the combustion chamber by means of the spark plug button 32, the gases rapidly expanding therein find an easier exit by way of the tail pipe or pipes 11, and once directed outwardly through the tail pipe or pipes 11 in the direction of arrow 36, the gaseous mass moves as a plug down the tail pipe and in so doing produces a suction effect through the unit 14, thus drawing therethrough a fresh charge of air or fuel-air mixture which enters the combustion chamber 10 and is exploded afresh therein. This cyclic action continues until the entrance air is cut off. Ignition is automatic when the unit is in operation; the spark plug is used for starting only. The reason for such automatic re-ignition in pulse jet engines is not understood. Various theories, none wholly proven, have been advanced, but the fact of such automatic re-ignition is well known. The introduction of fuel into the system may be accomplished conveniently by means of a Venturi horn 30 having a narrow throat section 38. A fuel supply pipe 39 which is fastened by means of a bracket and rivets 40 to the venturi 30 has a metering and spray nozzle 41 at the throat of the venturi. Thus, rapidly inflowing air draws fuel through the pipe 39 into the Venturi section where fuel-air mixture takes place, and the mixture enters in the direction of arrows 16 through the labyrinth passage. It will be noted that the gases passing in the direction of arrows 16 do not cause the swirling motion to nearly the extent that the swirling motion is caused by the reverse flow of gases. Hence, the charge readily enters through the labyrinth 14 into the combustion chamber. Fuel may also be introduced by means of a suitable pressure injection system through tube 26 terminating in a spray nozzle 27 located within the combustion chamber 10.

In Figure 2 the combustion chamber 50 is likewise provided with a tail pipe 51 which is connected by the reducing section 52. The starting ignition plug is shown at 53. In this instance the labyrinth passage consists of a section of the combustion chamber side wall shown above the bracket 55. In this section there is mounted a ogival pointed cylinder 58 which has a streamlined nose 59 fitting into the Venturi section 60. In the annular space shown opposite bracket 62—62 there is provided a helical path fomed by a metal helix of a plurality of turns, either single or double thread. The metal turns are illustrated at 63 and are fastened to the inside of the side wall tube 50 and the inner plug 58. The thin annular helical passage thus formed serves as a path through which the air or fuel-air mixture may enter the combustion chamber. Fuel injection may be by way of pipe 64 which extends centrally through the plug 58 and terminates in a spray bar shaped into a four-nozzle T illustrated at 65. Fuel may also be introduced through suction by means of pipe 68 which is mounted on the bell shaped mouth 70 of the venturi and extends to the throat 71 of the venturi. As high velocity air passes through the Venturi throat 71, fuel is drawn through the pipe 68 and the fuel-air mixture enters the helical passage. After a plurality of turns the mixture emerges in the direction of arrows 73, as illustrated in Figure 3. The swirling gases are then ignited, as previously described, and combustion occurs. The relatively great resistance offered by the helical passage as compared with the relatively much less resistance offered by the tail pipe 51 is sufficient to initiate the flow of the mass of gases down the tail pipe 51, and once moving in this direction they tend to continue so to move, and the moving plug of gases acts as a piston which serves to draw in the fresh charge through the annular passage which charge is then exploded and the operation repeated cyclically.

Since relatively little is presently known of the theoretical considerations governing the design and operation of pulse jet and ram jet devices, we will not dwell long on such considerations. We have in the course of our experiments to date, however, constructed and successfully operated upward of one hundred such devices differing widely as to size, shape, valving, cyclic frequency, etc. From this work we are enabled to present a few pertinent concepts.

First, when pulse jet devices are correctly proportioned the inlet air passage is such as to provide an extremely high velocity flow into the combustion chamber. In order to accomplish this high velocity flow a relatively large pressure differential is required, and hence the inlet area is relatively small in comparison to that of the tail pipe or pipes.

Next, our experience with valved units leads us to believe that the valve or valves must seat and seal off the air inlet for only an infinitesimal portion of time in each cycle, just sufficient to start the mass of expanding gases in the combustion chamber moving out the tail pipe or pipes. The seal at this moment need not be complete, since we have successfully operated some of our valved units with one valve removed, leaving a free open passage through the valve port between the air inlet and the combustion chamber. We have successfully operated units with one valve thus removed with no ram air supplied. We are thus led to believe that if a passageway having a high resistance to air flow in one direction is substituted for the valve mechanism, the cyclic operation can be successfully carried out and the valves dispensed with.

We have also operated some of our valved units with all valves removed, and they then operate only as ram jets. However, the cyclic function or pulse is still present and is not only definitely audible but has been made visible on an oscilloscope with a vibration pick-up. Hence, in our view the so-called ram jet devices are merely pulse jet devices which substitute ram air for valve action in order to start the gases moving rapidly out the tail pipe. Ram jet devices hitherto known require a high ram air velocity for successful operation. We believe this is so because it is the pressure increase of the ram air when its velocity is extremely rapidly and greatly reduced by the opposition of the cyclic explosion, that in effect acts as a valve and starts the mass of gases in the combustion chamber moving rapidly out the tail pipe, making possible the cyclic function.

We have hence designed pulse type units having no valves and inlet passages of relatively much smaller across sectional area than that of the outlet or tail pipes. In addition, these inlet passages are designed to restrict air flow in one direction.

In the example illustrated in Figure 1, the one way restriction is by means of vortex pockets 19–23. An extremely violent swirling motion will be set up in pocket 19 by the high velocity reverse flow of gases resulting from the explosion in combustion chamber 10. What reverse flow is not blocked by this vortex will pass on to pocket 20, forming another less violent vortex. The weakened reverse flow then passes to pocket 21, forming another vortex pocket and so on, becoming progressively weaker at each pocket. Thus, the velocity of ram air necessary for successful operation of a valveless pulse jet unit may be greatly reduced or dispensed with altogether.

The wall of the combustion chamber facing the air inlet in Figure 1 is shown shaped concavely in order to direct the main force of the explosion rearwardly out the tail pipe, thus enhancing the effect.

In Figure 2 the relatively small cross-sectional area of inlet passage is shown wound as a tight helix in order to provide the one way restriction. The entering high velocity air attains a very rapid swirl through this shaped passage, which swirl persists in the combustion chamber and through the combustion process. Reverse flow is momentarily blocked because the high velocity swirl must decelerate and reverse its rotation before reverse flow can take place.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that we do not limit ourselves to the specific embodiments herein except as defined by the appended claims.

What we claim is:

1. A resonant pulse jet device operable without mechanical valves comprising a combustion chamber having inlet and outlet passages at opposite ends thereof, an exhaust tube opening freely into said outlet passage and forming with

said combustion chamber a system resonant in gases, means including said inlet passage for introducing air into said combustion chamber in conjunction with the pulsating action of said resonating system when said gases are traveling toward the exhaust end of said tube, means for introducing fuel to form a combustible mixture in said combustion chamber, said inlet passage having low flow resistance for flows in the direction toward said combustion chamber and relatively high flow resistance for flows in the direction away from said combustion chamber to provide for said introduction of air under said pulsating action and for restriction of flow from the combustion chamber reversely through said inlet passage when the gases in said resonating system are traveling in the reverse direction toward said inlet passage in order to accomplish automatic cyclic combustion, scavenging, and charging resulting from said resonating operation, and a baffle forming a solid wall at the end of said combustion chamber and located in intercepting relation in the direct path of flow through said inlet passage for reducing reverse flow of gases through said inlet passage under said resonating operation.

2. A resonant pulse jet device operable without mechanical valves comprising a combustion chamber having inlet and outlet passages at opposite ends thereof, an exhaust tube opening freely into said outlet passage and forming with said combustion chamber a system resonant in gases, means including said inlet passage arranged in a generally annular shape for introducing air into said combustion chamber in conjunction with the pulsating action of said resonating system when said gases are traveling toward the exhaust end of said tube, means for introducing fuel to form a combustible mixture in said combustion chamber, said inlet passage having low flow resistance for flows in the direction toward said combustion chamber and relatively high flow resistance for flows in the direction away from said combustion chamber to provide for said introduction of air under said pulsating action and for restriction of flow from the combustion chamber reversely through said inlet passage when the gases in said resonating system are traveling in the reverse direction toward said inlet passage in order to accomplish automatic cyclic combustion, scavenging, and charging resulting from said resonating operation, and a solid wall inwardly of said annular inlet passage for reducing reverse flow of gases through said inlet passage.

3. A resonant pulse jet device operable without mechanical valves comprising a combustion

chamber having inlet and outlet passages at opposite ends thereof, an exhaust tube opening freely into said outlet passage and forming with said combustion chamber a system resonant in gases, means including said inlet passage opening into said chamber at a substantial angle to the axis thereof for introducing air into said combustion chamber in conjunction with the pulsating action of said resonating system when said gases are traveling toward the exhaust end of said tube, means for introducing fuel to form a combustible mixture in said combustion chamber, said inlet passage having low flow resistance for flows in the direction toward said combustion chamber and relatively high flow resistance for flows in the direction away from said combustion chamber to provide for said introduction of air under said pulsating action and for restriction of flow from the combustion chamber reversely through said inlet passage when the gases in said resonating system are traveling in the reverse direction toward said inlet passage in order to accomplish automatic cyclic combustion, scavenging, and charging resulting from said resonating operation, and a baffle having a curved surface forming a solid wall at the end of said combustion chamber adjacent said inlet passage for reducing reverse flow of gases through said inlet passage under said resonating operation.

4. The apparatus of claim 1 further characterized in that said means for introducing fuel into the said combustion chamber includes a fuel jet inlet orifice extending directly into said combustion chamber.

5. The apparatus of claim 1 further characterized in that said means for introducing fuel into the combustion chamber includes a Venturi section of said inlet passage having a throat of reduced cross section and a fuel inlet nozzle positioned in said Venturi throat.

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