

Sept. 15, 1959

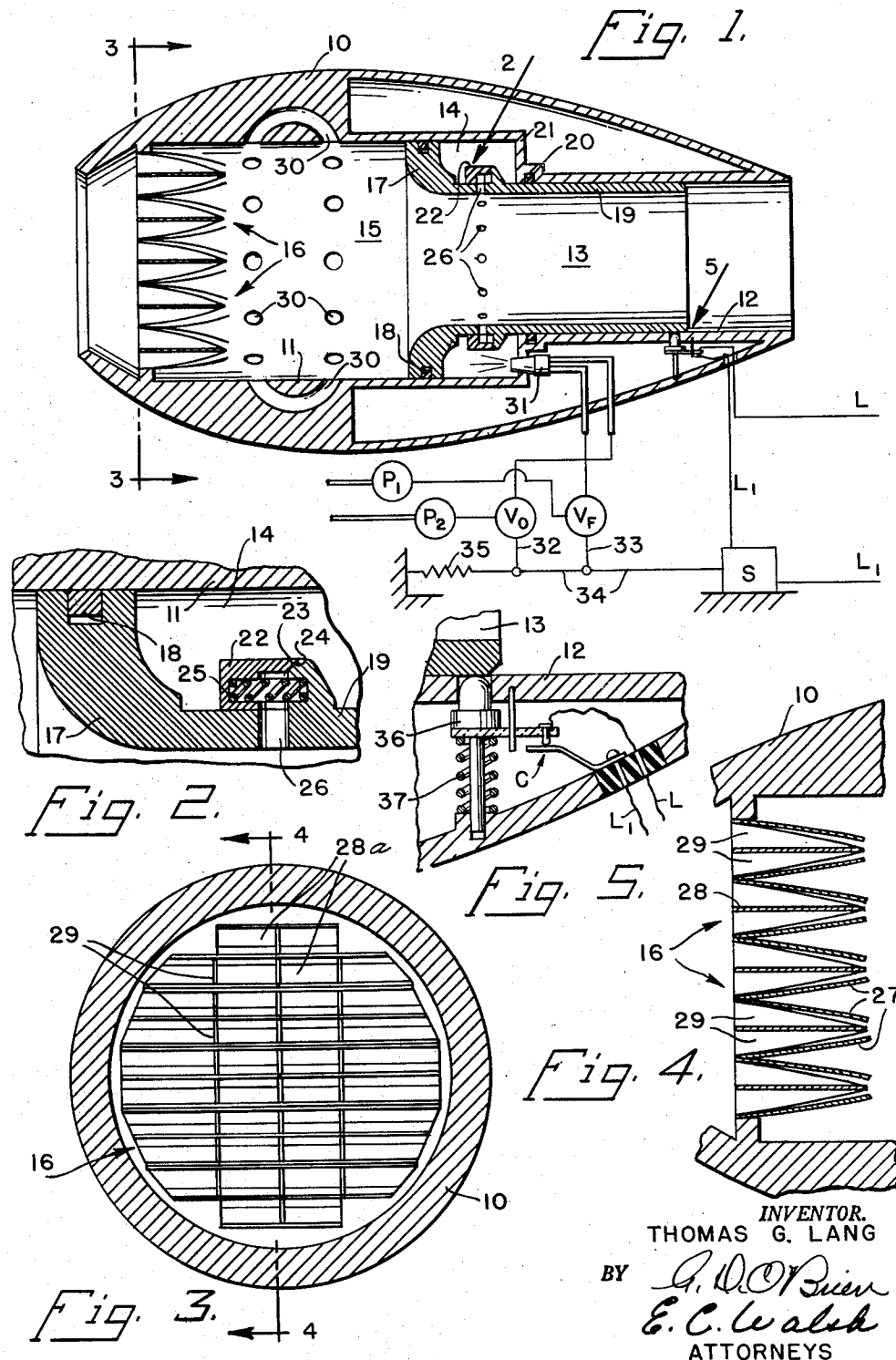
T. G. LANG

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PULSE JET

Filed May 11, 1953

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

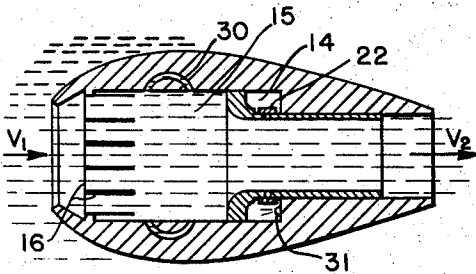


Fig. 6.

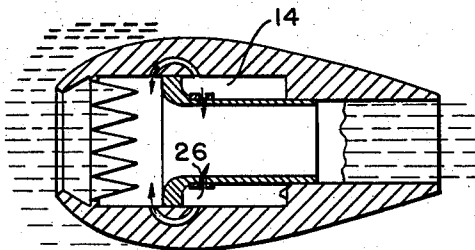


Fig. 6D.

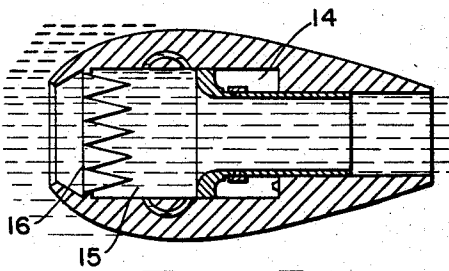


Fig. 6A.

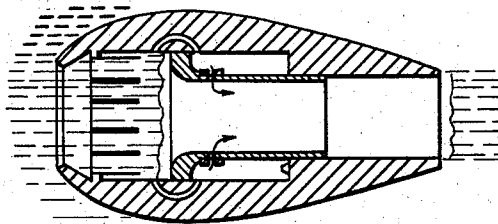


Fig. 6E.

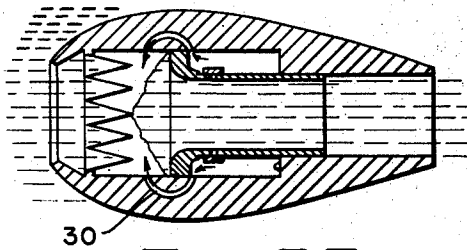


Fig. 6B.

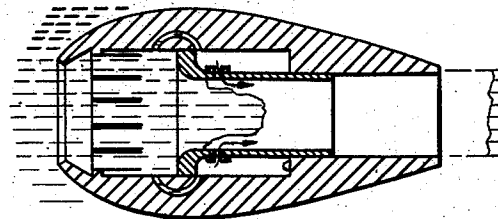


Fig. 6F.

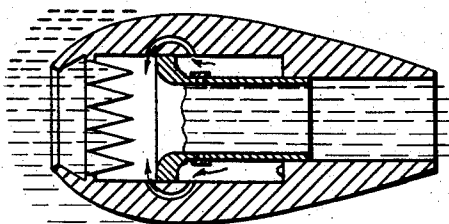


Fig. 6C.

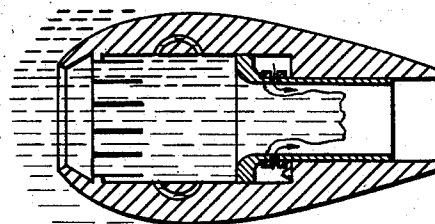


Fig. 6G.

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PULSE JET

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11 Claims. (Cl. 60—35.6)

(Granted under Title 35, U.S. Code (1952), sec. 266)

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.

This invention relates to improvements in hydraulic pulse jet devices for propelling surface and underwater craft or the like.

One of the objects of the invention is to provide a device of the class referred to which has improved thermodynamic efficiency.

Another object is to maintain expansible gases, which provide the propulsive energy, out of contact with a water jet, which produces the thrust, until the expansion of the gases is as complete as practicable to thus obviate heat losses to the water jet.

Another object is to produce a vehicle having optimum thrust for its size.

Another object is to provide increased efficiency by utilization of a cycle employing combustion at substantially constant volume.

Another object is to provide a high speed pulse jet which operates without cavitation.

Further objects, advantages, and salient features will become more apparent from a consideration of the description to follow, the appended claims, and the accompanying drawing, in which:

Fig. 1 is a longitudinal section of the subject of the invention, portions being shown diagrammatically;

Fig. 2 is an enlarged detail of the portion indicated by arrow 2, Fig. 1;

Fig. 3 is an enlarged section taken on line 3—3, Fig. 1; Fig. 4 is a section taken on line 4—4, Fig. 3;

Fig. 5 is an enlarged detail of the portion indicated by arrow 5, Fig. 1; and

Figs. 6 to 6G are sections similar to Fig. 1, showing various stages in the cycle of operation of the invention.

Referring in detail to the drawing, and particularly Figs. 1 to 5, the subject of the invention comprises, in general, a thrust producing device 10 having axially extending bores 11, 12 therein in which a piston 13 is reciprocally slideably disposed, an expansible gas chamber 14, and an expansible gas and water chamber 15 adapted to be alternately closed and opened at its forward end by a one way or check valve 16.

Piston 13, formed as an annulus open at both ends, is provided with an outwardly projecting flange portion 17, the periphery of which slides in bore 11 and is sealed therealong by seal or piston ring 18 of any suitable type known in the art, and a portion 19 which slides within bore 12 and is sealed therealong by a similar seal ring 20, disposed within an annular groove around bore 12. Due to the difference in the diameters of the bores, flange 17, bore 11, portion 19, and annular wall 21 form the chamber 14 previously referred to. As best shown in Fig. 2, an annular axially slideable valve member 22 surrounds the piston and is provided with a seat 23 which engages a mating seat 24 on the piston. A plurality of angularly spaced springs 25, one of which is illustrated, urge valve

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22 toward its open position, whereby chamber 14 may communicate with chamber 15 through ports 26.

Valve 16, as best shown in Figs. 3 and 4, is of the grid and reed type, comprising a plurality of resilient thin plates or reeds 27 which are fixed at their forward ends to grid 28 and adapted to flex to open and close the passageways 28a between webs 29 in response to difference in pressure between water at the front or left end of the valve and the pressure of fluid in chamber 15. As shown in Fig. 4, the reeds are in partially opened position and move between full open positions, wherein they are disposed substantially parallel, and closed positions wherein they conform to the outer surfaces of webs 29. Valves of this type are well known in the art.

A plurality of angularly spaced by-pass conduits 30 communicate chambers 14, 15 when flange 17 of the piston is disposed between ends of these conduits, the operational purpose of which will subsequently be described in greater detail.

While any suitable expansible gas may be employed in chamber 14 to actuate the piston, the exemplary construction illustrated may be considered as one of the type employing a liquid fuel and liquid oxidant adapted to spontaneously react when mixed to form products of combustion, these reactants being well suited for use when the device forms the propulsion system of a torpedo. As diagrammatically illustrated in Fig. 1, a fuel is supplied to mixing nozzle 31 by a pump P_1 through valve V_1 , and an oxidant by pump P_2 through valve V_2 . Valves V_1 , V_2 are adapted to be actuated by kinematic linkage, such as levers 32, 33, connected to link 34, the latter being urged by a spring 35 to close the valves and by a solenoid S to open the valves against the urge of the spring. The solenoid is energized by an electric circuit including lines L, L_1 and switch C, the latter adapted to be moved to closed position, as best shown in Fig. 5, by a reciprocable switch actuator 36 urged toward bore 12 by a spring 37 and in the opposite direction by the rear end of piston 13 when it overrides the portion of the actuator projecting into the bore in the path of movement of the piston. The fuel and fuel system just described may be bodily carried by the device or by other water craft to which the device may be attached. As will also be apparent any other suitable expansible gas may be employed such as the products of combustion of a hydrocarbon and oxygen.

In the operation of the device, which is diagrammatically depicted in Figs. 6 to 6G, and referring first to Fig. 6, it will be assumed that the device is moving through water which may flow through valve 16 at a velocity of V_1 and that the piston has reached the rear end of its stroke and a fuel-oxidant has been injected into chamber 14 under control of switch C to produce expansible products of combustion under pressure. The increased pressure in chamber 14 acts on the front face of valve 22, tending to close it and gas leaking past seat 23 acts on the valve tending to open it. The pressure in chamber 23 is, however, ambient low pressure and since there must be a pressure drop across seat 23 the total pressure tending to open the valve is less than the total pressure in chamber 14 tending to close it. In addition, the inertia of the valve tends to close it when piston 17 suddenly moves forwardly. Valve 16 which was open at the beginning of the stroke is closed by pressure imparted to the water in chamber 15 by the forward movement of the piston. As the piston moves forward, as shown in Fig. 6A, water is being forced rearwardly from chamber 15 at a velocity V_2 , greater than V_1 , producing jet thrust to the device. When the piston moves to the position shown in Fig. 6B, gas passes from chamber 14 to chamber 15 through conduits 30, this being illustrated as a void between valve 16 and the water remaining in chamber 15. Fig. 6D illustrates the piston

at the forward end of its stroke. The gas has now expanded to such extent that its pressure in chamber 14 will no longer retain valve 22 closed, which now opens and permits gas to pass through ports 26 forcing more water rearwardly from chamber 15. As this pressure continues to drop the velocity or ram pressure at the front of valve 16 will exceed the pressure in chamber 15 and open valve 16 as shown in Fig. 6E wherein water is now entering chamber 15 through valve 16. When this water contacts the piston its velocity pressure forces the piston rearwardly on its return stroke as shown in Fig. 6F. Fig. 6G illustrates the piston closely approaching the rear end of its stroke with water continuing to fill chamber 15. When the piston reaches the rear end of its stroke chamber 15 is again filled with water and the cycle is completed. As will be apparent, valve 22 remains open during the return stroke of the piston not only to permit expansion of gas from chamber 14 to chamber 15 for the purpose previously described, but also to prevent entrapment of any gas in chamber 14 which has expended its expansive energy and which would otherwise require compressing by the rearward movement of the piston.

Referring again to Figs. 6 to 6B, and first to Fig. 6, the piston starts moving forwardly or to the left at a relatively high velocity since the pressure in chamber 14 is maximum at the beginning of the stroke of the piston. This in turn imparts a relatively high velocity to the water jet passing rearwardly through the piston. As the piston advances toward the forward end of its stroke its velocity decreases, however, since the pressure in chamber 14 decreases. In some instances, unless otherwise provided for, the difference between the jet and piston velocities would be sufficient to cause cavitation in the jet flowing through the piston since the body of water ahead of the piston is substantially static. This is minimized, however, by bypassing gas through ports 30, as best shown in Fig. 6B, in such manner that the gas flows into chamber 15 at points between the body of water referred to and valve 16. This imparts a rearward velocity to this body of water which prevents separation (cavitation) between it and the jet flowing through the piston.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. An underwater propulsion device comprising a variable volume water chamber adapted to intermittently receive ambient water, a variable volume gas chamber, and an oscillatable member adapted to be moved by gas in the gas chamber to increase the volume of the latter and simultaneously decrease the volume of the water chamber when it moves in one direction of its oscillation and to decrease the volume of the gas chamber and simultaneously increase the volume of the water chamber when it moves in the opposite direction of its oscillation, the device being constructed and arranged to discharge, in a direction substantially opposite to its direction of movement through the ambient water, at least a portion of the water in the water chamber when the member is moving in said one direction, whereby thrust is imparted to the device, said member adapted to be moved in said opposite direction by water entering the water chamber, and means for communicating the chambers when the gas chamber has increased to a predetermined volume, whereby gas may flow from the gas chamber into the water chamber and force water therefrom.

2. An underwater propulsion device comprising a water chamber, a valve adapted to intermittently admit ambient water into the water chamber, a gas chamber, and an oscillatable member adapted to be moved in one direction of its oscillation by gas in the gas chamber to increase the volume of the gas chamber and decrease the volume of the water chamber to effect discharge of

water therefrom in a direction substantially opposite to the direction of movement of the device through the ambient water, said valve being closed while the water is being discharged from the water chamber, said valve adapted to open after said member has moved to a limit position in said one direction and permit water to enter the water chamber, the water entering the water chamber adapted to move said member in its opposite direction of oscillation to its other limit position wherein its cycle of oscillation is completed.

3. Apparatus in accordance with claim 2 including means for communicating the chambers when the gas chamber has increased to a predetermined volume, to permit expansion of the gas in the water chamber for forcing water therefrom.

4. Apparatus in accordance with claim 2 including valve means for permitting flow of gas from the gas chamber when said member is moving in said opposite direction.

5. Apparatus in accordance with claim 4 wherein said valve means is bodily carried by the oscillatable member.

6. Apparatus in accordance with claim 4 wherein said valve means is so arranged to permit flow of gas from the gas chamber into the water chamber.

7. Apparatus in accordance with claim 4 wherein said valve means is adapted to be actuated to open position when the pressure in the gas chamber falls to a predetermined value, a rise of pressure in the gas chamber to another predetermined value adapted to close said valve means.

8. A pulse jet device comprising; an oscillatable member forming a wall between a variable volume gas chamber and a variable volume water chamber, the wall adapted to increase the volume of one chamber and simultaneously decrease the volume of the other chamber when it moves, the wall adapted to be moved in one direction of its oscillation by gas formed as products of combustion adapted to at least partially expand in the gas chamber out of contact with the water and in its opposite direction of oscillation solely by pressure of water entering the water chamber, the construction and arrangement being such that water is discharged from the water chamber when the member is moving in said one direction.

9. Apparatus in accordance with claim 10 including means for delivering the partially expanded gas to the water chamber for further expansion therein.

10. Apparatus in accordance with claim 10 including means for delivering fuel to the gas chamber when it is at substantially minimum volume for combustion therein at substantially constant volume, the products of combustion adapted to substantially adiabatically expand in the gas chamber.

11. An underwater propulsion device comprising an elongated tube open at opposite ends thereof and through which water may flow, an axially reciprocable tube disposed within the elongated tube having an end wall in sliding and sealing engagement with the first named tube, the tubes being constructed to provide an annular expandible chamber therebetween, portions of the inner wall of the first tube and the inner and end walls of the second tube forming an expandible water chamber, valve means near the forward end of the water chamber adapted to be opened and closed in response to pressure difference of water at opposite sides thereof, means for intermittently supplying an expandible gas to the annular chamber to move the second tube forwardly and increase the volume of the annular chamber and simultaneously decrease the volume of the water chamber, said movement increasing the water pressure in the water chamber and closing said valve means, continued forward movement forcing water from the second chamber rearwardly of the device at a velocity to effect forward propulsion thereof, means communicating the two chambers when the second tube has moved to its forward limit of movement whereby expand-

ing gas in the annular chamber may enter the forward end of the water chamber and effect further delivery of water rearwardly of the device, said valve being adapted to open when the pressure in the water chamber falls to a certain value and permit entry of water through the valve to force the second tube rearwardly to its rearward limit of movement, and other valve means adapted to remain open as the tube moves rearwardly to permit exhaust of gas remaining in the annular chamber.

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