Nov. 13, 1934. R. H. GODDARD 1,980,266

PROPULSION APPARATUS

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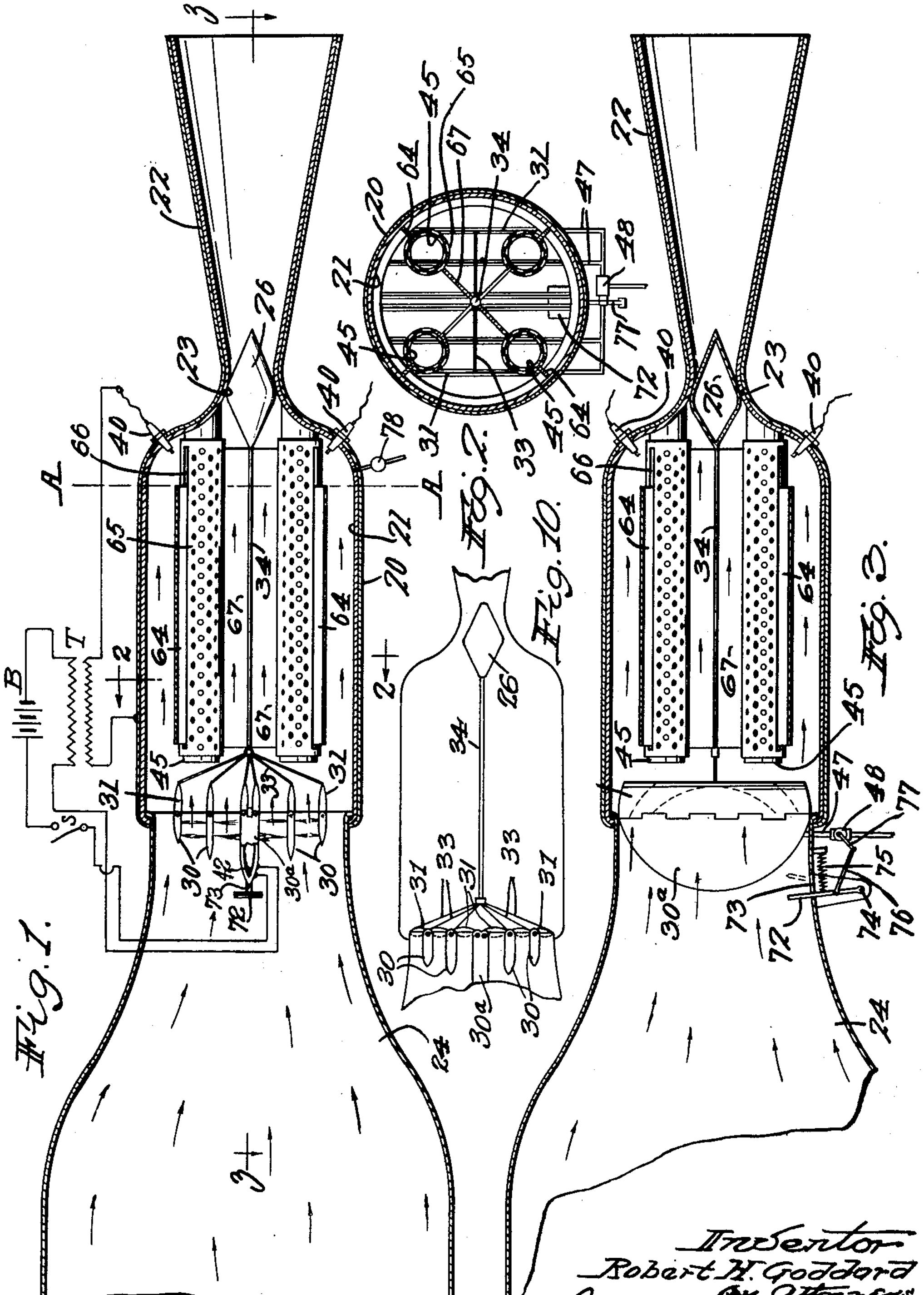

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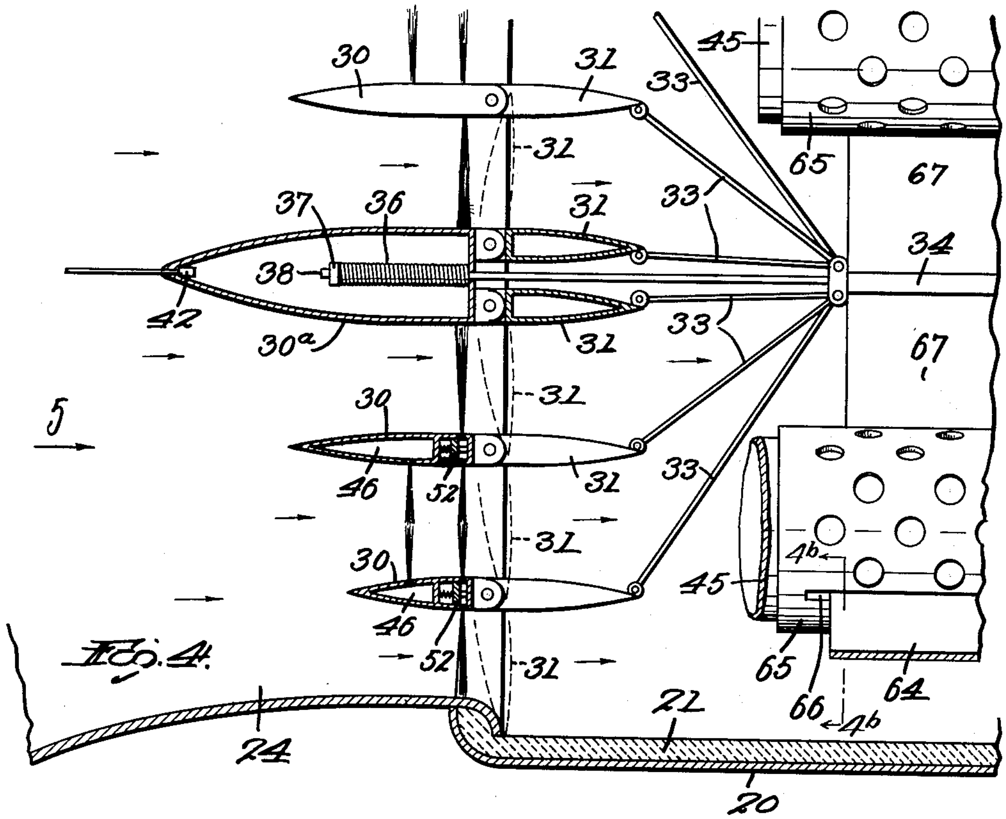

Fig. 4.

Fig. 4b.

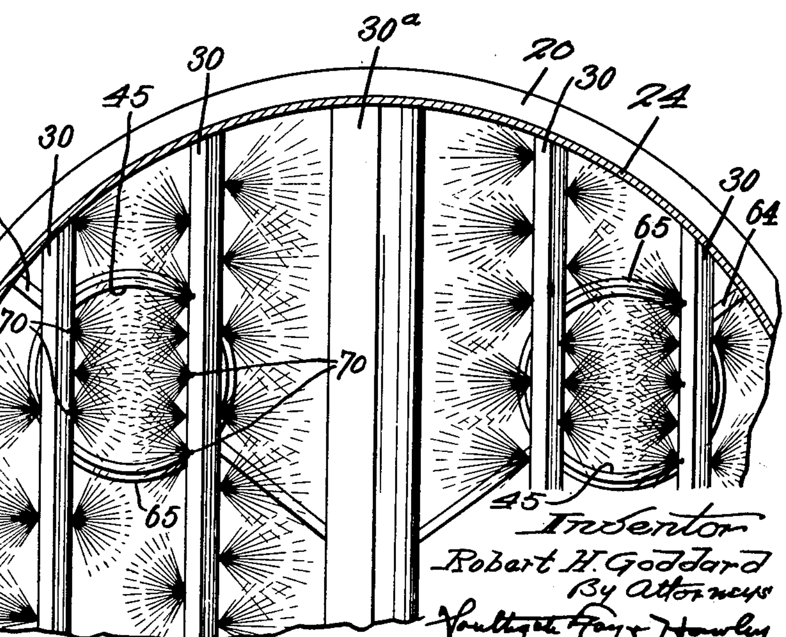

Fig. 5.

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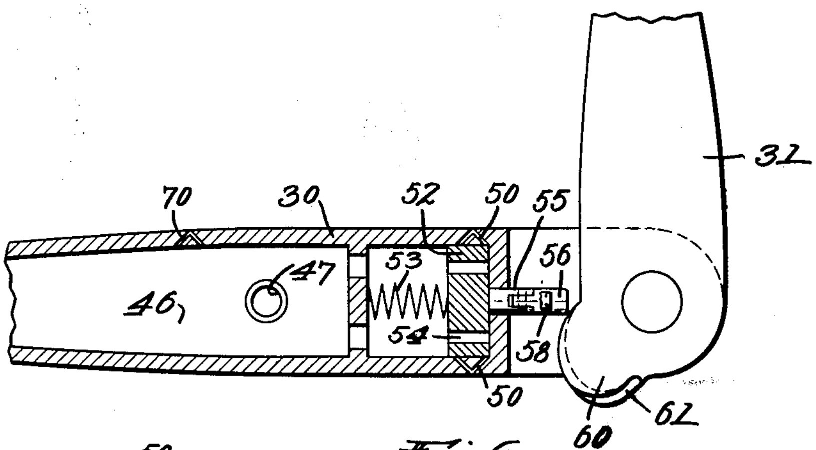

Fig. 6.

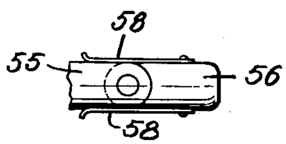

Fig. 6a.

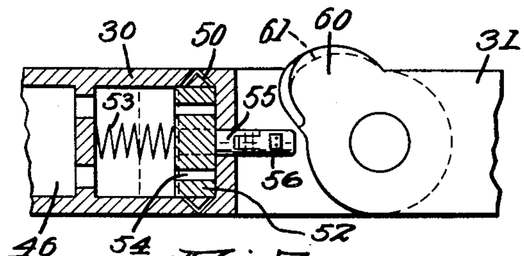

Fig. 7.

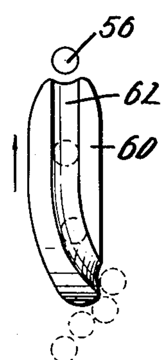

Fig. 8.

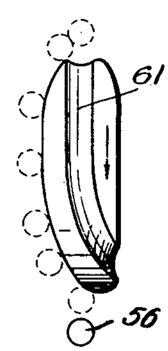

Fig. 9.

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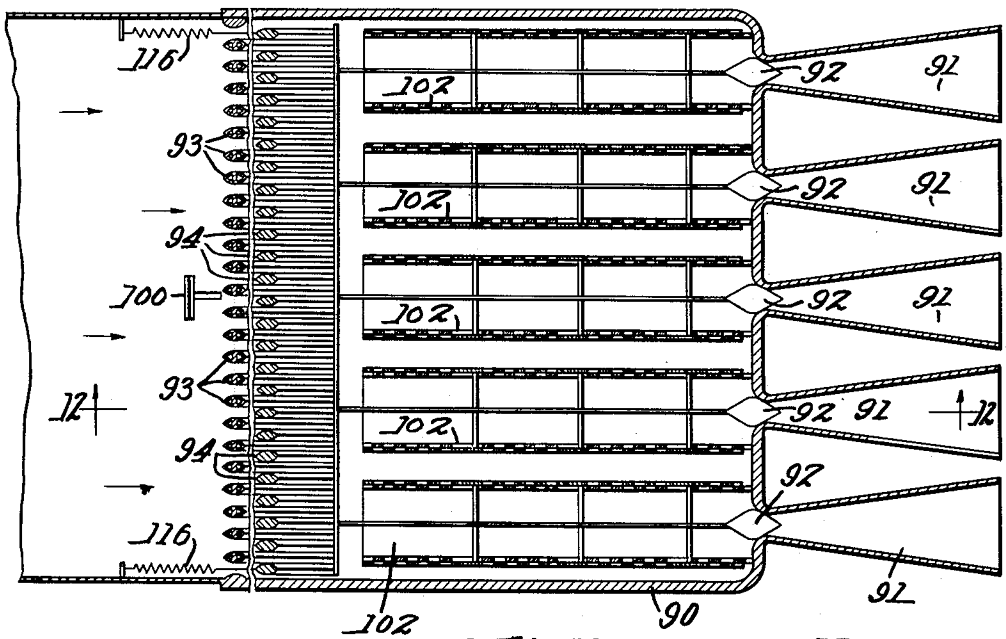

Fig. 11.

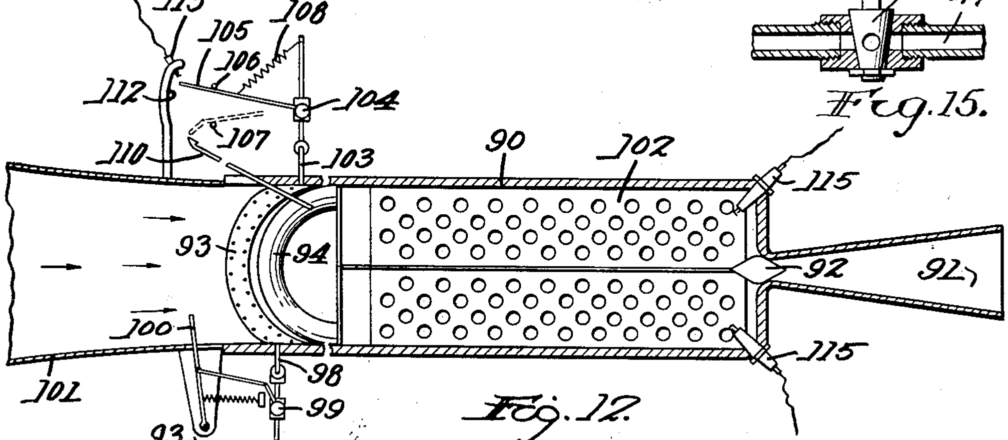

Fig. 12.

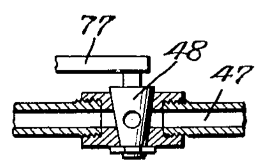

Fig. 15.

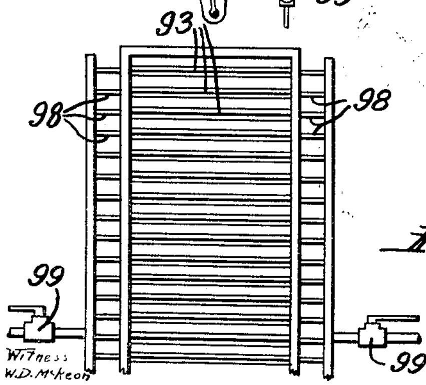

Fig. 14.

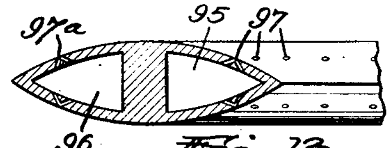

Fig. 13.

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UNITED STATES PATENT OFFICE

1,980,266

PROPULSION APPARATUS

Robert H. Goddard, Worcester, Mass.

Application February 7, 1931, Serial No. 514,289

18 Claims. (Cl. 60—44)

This invention relates to apparatus used for obtaining a propulsion effect from the combustion of a mixture of fuel and air or other oxidizing agent.

More specifically, the invention relates to apparatus in which the propelling effect is produced by the discharge of the products of combustion through a nozzle extending rearward in the line of flight or of gas discharge.

It is the object of my invention to provide apparatus by the use of which a very dilute fuel mixture may be utilized and by which it may be more effectively consumed in the combustion chamber.

Another object is to provide a propulsion apparatus in which the admission and firing of the propelling mixture is automatically effected by the pressure developed by the relative movement between the apparatus and the surrounding atmosphere.

An important feature of the invention relates to the provision of apparatus effective to supply a richer mixture at the discharge end of the combustion chamber and a thinner mixture toward the opposite end of the chamber.

I also provide auxiliary containers within the chamber, adapted to contain a relatively rich mixture throughout the length of the chamber.

It is also an object of my invention to provide means for regulating the fuel supply in accordance with the mass of air entering the combustion chamber, taking into account both its density and its relative velocity.

My invention further relates to arrangements and combinations of parts which will be hereinafter described and more particularly pointed out in the appended claims.

Two forms of the invention are shown in the drawings, in which

Fig. 1 is a sectional side elevation of one form of my improved propulsion apparatus;

Fig. 2 is a sectional plan view, taken along the line 2—2 in Fig. 1;

Fig. 3 is a sectional elevation, taken along the line 3—3 in Fig. 1;

Fig. 4 is an enlarged sectional side elevation of the valve mechanism shown in Fig. 1;

Fig. 4^b is a detail sectional view, taken along the line 4^b—4^b in Fig. 4.

Fig. 5 is a sectional plan view, looking in the direction of the arrow 5 in Fig. 4;

Fig. 6 is an enlarged sectional elevation of a portion of one of the valves and showing the fuel control devices;

Fig. 6^a is a detail view of a yielding cam follower to be described;

Fig. 7 is a view similar to Fig. 6 but showing the movable valve in a different position;

Figs. 8 and 9 are detail views showing the operation of the cam which controls the fuel admission;

Fig. 10 is a partial sectional side elevation similar to Fig. 1 but showing certain parts in a different position.

Fig. 11 is a sectional side elevation of a modified construction;

Fig. 12 is a sectional elevation, taken along the line 12—12 in Fig. 11;

Fig. 13 is a sectional view of one of the valve members;

Fig. 14 is an end elevation of a portion of the valve mechanism, looking from the left in Fig. 12, and

Fig. 15 is a detail sectional view of a fuel valve.

Referring to the form of my invention shown in Figs. 1 to 10, I have provided a combustion chamber 20, preferably having a thin sheet metal outer wall and preferably lined with a layer 21 of a refractory and heat-insulating material. A discharge nozzle 22, similarly lined, is connected to the rear or discharge end of the chamber 20 and may desirably be formed integral therewith.

A stream line air-collecting device or funnel 24 is attached to the forward end of the combustion chamber 20 and the admission of air from the funnel 24 to the chamber 20 is controlled by valve mechanism to be described.

A movable device 26 controls the restricted passage 23 between the chamber 20 and the discharge nozzle 22. This device 26 is preferably in the form of a hollow metal plug, as indicated in Fig. 3, which is movable into the restricted passage 23 from the forward end but which cannot pass therethrough.

Air admission

The flow of air from the funnel 24 to the combustion chamber 20 is regulated by valve mechanism comprising a plurality of fixed valve members 30 and movable valve members or vanes 31 pivotally connected thereto. The vanes 31 (Fig. 4) are connected by links 33 to an actuating rod 34 extending along the axis of the combustion chamber 20 and attached at its rear end to the plug 26.

When the vanes 31 are in the open position indicated in full lines in Fig. 4, the plug 26 is in its rearmost position, closing the restricted passage

23 between the chamber 20 and the discharge nozzle 22.

When the vanes 31 move to the closed position indicated in dotted lines in Fig. 4, the plug 26 is drawn forward, thus leaving an open connection between the combustion chamber 20 and the discharge nozzle 22. Such closing movement of the vanes 31 is effected by a coil spring 36 (Fig. 4) mounted in an enlarged middle fixed valve member 30a and acting upon a collar 37 on the forward end of an extension 38 of the rod 34.

A plurality of spark-plugs 40 are spaced about the rear end of the combustion chamber 20, and the circuit through these spark-plugs is completed by engagement of the front end of the rod extension 38 with a contact 42 (Figs. 1 and 4) in the extreme front end of the valve member 30a. This contact is engaged as the vanes 31 reach their closed position, so that the fuel mixture is ignited when the admission valves are closed and the discharge passage 23 to the nozzle 22 is open.

A suitable ignition circuit is shown diagrammatically in Fig. 1 which indicates a battery B and switch S in circuit with the contacts 38 and 42 (Fig. 4) and also with the primary coil of a transformer T. One side of the secondary coil of the transformer is grounded on the casing of the ignition chamber and the other terminal is connected to the spark-plug 40. The switch S is manually closed to effect the first explosion.

The opening of the vanes 31 is occasioned by the pressure of the air in the funnel 24 after the previous charge of fuel has been ignited and after the gases have passed out through the discharge nozzle 22, with a corresponding return of the combustion chamber to normal pressure, which may be below atmospheric.

When the air pressure in the funnel 24 overcomes the resistance of the spring 36, the vanes 31 move to the open full line position indicated in Fig. 4 and the plug 26 simultaneously closes the discharge passage 23. Air then flows into the chamber 20 until a pressure is built up therein corresponding to the pressure in the funnel 24, after which the vanes 31 are again closed by the spring 36. During this admission of air, fuel is also admitted by mechanism which will now be described.

Fuel admission

This admission of fuel is in two distinct steps. By one step, fuel is admitted to the combustion chamber 20 during the initial movement of the vanes 31 to their open position, but this admission of fuel is interrupted as the vanes reach their open position, so that in the combustion chamber we have a relatively rich fuel and air mixture at the rear or discharge end of the chamber, and a relatively thin mixture, largely air, at the front end of the combustion chamber. This difference in richness of the fuel mixture is occasioned by the fact that fuel is admitted to the chamber only during the initial opening of the vanes and not during the subsequent building up of air pressure in the chamber.

By the second step, fuel is admitted to certain auxiliary containers 45 within the chamber 20 (to be described) during the entire time that the vanes 31 are open, so that a relatively rich mixture is supplied throughout the entire length of the auxiliary containers 45.

I will now describe in detail the mechanism for admitting fuel to the combustion chamber proper during the initial or opening movement of the vanes 31.

Referring particularly to Figs. 6 to 9, the fixed valve members 30 are provided with transverse passages 46 connected at their ends to a fuel supply pipe 47 (Fig. 3), which is connected to any suitable source of liquid or gaseous fuel and which is provided with a control valve 48. Converging perforations 50 (Fig. 6) are formed in the side walls of the fixed valve member 30 at intervals across the width of the combustion chamber 20. These openings 50 are normally closed by a valve member or plate 52, normally held in the position indicated in Fig. 6 by springs 53, in which position the plate 52 closes the perforations 50.

When the valve plate is raised against the pressure of the springs 53, the perforations are uncovered and a fine mist of fuel is ejected therethrough in the form of a fan-shaped spray. Openings 54 through the plate 52 permit free passage of the fuel to the perforations 50 and also equalize the pressure on the opposite sides of the plate 52 in all positions thereof.

Studs 55 in the plates 52 extend through guide openings in the end of the fixed valve member 30 and are provided with pivoted end portions 56 mounted thereon to yield in either direction. The end portion 56 is yieldingly held in alignment with the stud 55 by flat springs 58 (Fig. 6a) secured to the member 56 and engaging the sides of the stud 55.

Cam projections 60 are formed on the movable vanes or valve members 31 opposite the studs 55 and the end portion 56 thereof. The cam portions 60 are provided with cam grooves 61, as indicated in Figs. 8 and 9, which are offset axially toward one end thereof.

As the vanes 31 move from the closed position shown in Fig. 6 to the open position shown in Fig. 7, the end portions 56 of the studs 55 enter the grooves 61 at the straight or open ends thereof, as viewed in Fig. 8, and are raised thereby, thus lifting the valve plate 52 and allowing fuel to flow through the perforations 50.

As the vanes 31 continue their opening movement, the end portions 56 are displaced laterally by the cam grooves 61 and eventually pass out of the grooves and return to their initial positions, as indicated by the successive dotted circles in Fig. 8. The valve plate 52 is thus lifted and the perforations 50 opened during the initial opening movement of the valves 31 but closes as the valves reach fully open position.

On the return movement of the vanes 31 to closed position, the end portions 56 are displaced sidewise in the opposite direction by the cam portions 60. Instead of entering the grooves 61, they slip along the sides of the portions 60, as indicated by the successive dotted circles in Fig. 9, so that no opening effect is produced by the cams 60.

Auxiliary containers

The auxiliary containers 45 (Fig. 4) are in the form of perforated hollow sheet metal tubes, secured at their rear ends to the rear end wall of the combustion chamber 20 adjacent the discharge passage 23. At their forward ends, they are open to receive the fuel mixture supplied thereto. The compartments 45 are also preferably secured to the side walls of the chamber 20 by longitudinally extending plates or partitions 64 (Figs. 4 and 5).

Perforated sleeves 65 (Fig. 4) are slidably mounted on the outside of the tubular containers 45 and are slotted as indicated at 66 to clear the plates 64. These perforated sleeves 65 are connected by plates or partition members 67 to the axially extending operating bar 34 previously described, so that the sleeves 65 move axially with the bar 34 and plug 26 during the opening and closing of the valves or vanes 31. The perforations in the containers 45 and the sleeves 65 are so located that the two sets of perforations will coincide when the sleeves 65 are moved forward with the closing of the vanes 31 and the removal of the plug 26 from the discharge passage 23.

In order to supply fuel to the auxiliary containers 45, I provide additional pairs of perforations 70 (Fig. 6) in the forward part of the fixed valve members 30, communicating directly with the transverse passages 46. These openings or perforations 70 are disposed directly in line with the auxiliary containers 45, as indicated in Fig. 5, and the fuel spray from these perforations passes directly into the auxiliary containers. This flow of fuel through the perforations 70 takes place throughout the filling of the combustion chamber 20 with fuel and air.

Fuel control

The supply of fuel to the transverse passages 46 is controlled by the valve 48 previously described. I have provided special mechanism for opening and closing this valve in accordance with the mass of air entering the combustion chamber 20 through the funnel 24.

For this purpose, I provide a vane or blade 72 (Figs. 2 and 3) extending through a slot 73 into the contracted portion of the funnel 24. The vane 72 is mounted on a fixed pivot 74 and is normally held in forward position by a compression spring 75.

The vane 72 is connected by a link 76 to an arm 77 mounted on the movable member of the valve 48. The spring 75 normally holds the valve 48 closed, so that no fuel will flow to the transverse passages 46 in the fixed valve members 30.

When air flows into the combustion chamber through the funnel 24, the dynamic pressure of the air against the vane 72 will compress the spring 75 and open the valve 48 and the amount of opening movement will depend upon both the density of the air and also the velocity of the air with respect to the velocity of the chamber 20, or, in other words, upon the mass of air admitted.

As the chamber becomes filled with air and the movable valve members 31 close, the flow of air past the vane 72 ceases and the valve 48 automatically closes.

I thus provide means by which a spray of fuel is admitted to the auxiliary containers 45 during the entire filling of the combustion chamber 20 with fuel or air. Accordingly, I have a relatively rich mixture throughout the entire length of the containers 45, while the combustion chamber itself has a rich mixture only in the extreme rear portion, this rich mixture ordinarily extending forward about to the line A—A in Fig. 1.

Operation

Having described the details of construction of this form of my propulsion apparatus, the method of operation thereof will be readily apparent. The apparatus may be initially charged by the use of an auxiliary carburetor 78 (Fig. 1) through which a charge of explosive mixture may be injected under suitable pressure and this charge may be fired by manually completing the circuit through the spark-plugs 40. This will start the apparatus in rapid motion and as soon as the gases of combustion thus produced are discharged through the nozzle 22, the pressure of air in the funnel 24 will open the valves 31 and simultaneously close the nozzle 22 by inserting the plug 26. (See Fig. 1.)

On the opening of the valves 31, air will enter the chamber 20 from the funnel 24. A part of this air will come to rest at the rearward end of the chamber 20 adjacent the plug 26 but at the forward end of the chamber 20 the remaining air will surge forward immediately after ceasing its rearward movement, the action being similar to water-hammer.

As the valve members 31 open, the cams 60 operate as previously described to admit a charge of fuel to the rear end of the combustion chamber, such action taking place, however, only during the opening movement of the valve members 31. At the same time, however, fuel is admitted to the auxiliary containers 45 and such admission to these containers continues until the chamber 20 is full of the fuel mixture.

The forward surging of a part of the air then assists the spring 36 (Fig. 4) to close the valves 31 and to move the several parts connected with these valves. At the same time, the rod 38 engages the contact 42 and completes a circuit through the spark-plugs 40.

It should be noted that the differential pressure due to this forward surging air adjacent to the valves 31 is the only air pressure acting effectively to move the valves during the valve-closing operation. The static pressure due to the compression of the air in the chamber 20 will be the same on both sides of the valves 31 and will induce no turning action.

It should also be noted that at high speeds substantial forward surges of air will occur in the forward end of the chamber 20 adjacent the valves 31 and that the force of these air surges acts on the valves 31 which are of comparatively large area. On the other hand, the opening 23 is relatively small and the fall in pressure in the nozzle 22 due to ejector action is also relatively small, being not over fourteen pounds per square inch for speeds up to one thousand feet per second, at which speed the air surges will be relatively heavy.

It is therefore clear that the forwardly surging air forces acting on the valves 31 will be effective to close the valves 31 and to move the parts associated therewith, overcoming any opposing force exerted on the plug 26.

The compression obtained in the chamber 20 is only slightly reduced when the plug 26 is moved forward by the closing of the valves, owing to the small size of the opening 23 and to the almost imperceptible time interval before ignition takes place.

The new charge is thus fired, the richer portion of the charge at the rear of the combustion chamber taking fire at once and the combustion proceeding toward the front end of the chamber as the richer fuel in the containers 45 passes through the perforated tubes and mingles with the air in the chamber 20.

Combustion also proceeds forwardly in the containers 45. A spark-plug 40 is provided adjacent each container 45 so that this progressive combustion may be started simultaneously in all of the containers and may proceed uniformly throughout their length.

The high pressure of the explosion will force the exhaust gases rapidly through the opening

23 and out of the nozzle 22, and the inertia of the rapidly moving gases in the exhaust nozzle will thereafter reduce the pressure in the chamber 20 to a pressure below atmospheric.

The air compressed in the rear end of the funnel 24 just forward of the valves 31 will then act with the low pressure in the chamber 20 to force the valves 31 open immediately after the explosion. Such exhaust gases as remain in the chamber 20 will pass out of the opening 23 before the plug 26 is again seated.

The air passing through the spaces between the fixed valve members 30 will be charged with fuel introduced in the form of spray as previously described. The air and fuel mixture will again come to rest at the rear end of the chamber and will surge forward at the forward end, assisting the spring 36 to again close the valves 31 and this cycle of operations will be thereafter continuously repeated.

It will be noted that the flow of fuel and air is all in the same rearward direction and that the stream-line surfaces of the valve members interfere as little as possible with such rearward flow. The gas and fuel thus mix naturally and there is very little loss of kinetic energy due to variations in relative speed of the gases. Also there is very little loss of heat during the period of mixing of the rich gases in the containers 45 with the more diluted gases in the chamber 20. Such loss is serious where a jet of hot gas is projected into a large body of much cooler gas. There is also a loss of kinetic energy when the hot gas is projected into the cooler gas at high speed.

While the device is used for rocket propulsion or for other similar purposes, the speed of the apparatus produces a pressure substantially above atmospheric in the nozzle 24. When used for stationary apparatus, a similar effect may be produced by developing a pressure below atmospheric during the discharge of the gases from the combustion chamber 20. Many suitable uses for the discharge gases may be developed.

Larger units

In Figs. 11 to 14 I have shown a modified construction adapted for use where very large combustion chambers are required. In this case, the combustion chamber 90 is provided with a plurality of discharge nozzles 91, each controlled by a plug or stopper 92 as previously described.

The valves in this case are in the form of a fixed grid 93 and a movable grid 94. The fixed grid or valve members 93 are provided with transverse passages 95 and 96 (Fig. 13) and with spray openings 97 and 97^a. Fuel is admitted to the transverse passages 96 through a pipe 98 and valve 99 (Fig. 12) and the operation of the valve 99 is controlled by a vane 100 in the funnel 101, as in the form previously described. Consequently, fuel is delivered through the spray openings 97^a to auxiliary containers 102 in the chamber 90 so long as the grid 94 is open.

Fuel is admitted to the transverse passages 95 through a pipe 103 having a valve 104. The movable member of the valve 104 is provided with a flexible arm 105 movable between stops 106 and 107 and normally held against the stop 106 by a spring 108. The valve 104 is closed when the arm 105 engages the stop 106 and is fully open when the arm 105 engages the stop 107. The valve begins to open as soon as the arm 105 starts to move away from the full line position shown in Fig. 12. An actuating member 110 is mounted on the movable valve grid 94. As the valve moves forward to close, the hook-shaped end of the member 110 engages the fixed cam plate 112. The member 110 is flexibly mounted so that it slides along the cam member 112 until it hooks over the end of the arm 105. At the same time the member 110 engages a contact 113 and completes the circuit through the spark-plugs 115 in the combustion chamber 90, which circuit corresponds in all respects to the circuit previously described and shown in detail in Fig. 1.

When the movable valve grid 94 thereafter moves rearward, the arm 105 is swung about its pivot against the tension of the spring 108 until it strikes the stop pin 107, around which it bends until the hook-like end of the member 110 slips off of the end of the arm 105, which then returns to its initial position.

During this opening and return movement of the arm 105, fuel is admitted through the spray openings 97 to the rear portion of the combustion chamber 90, as in the form previously described. Fuel continues to be admitted through the spray openings 97^a to the auxiliary containers 102 until the air pressure in the chamber 90 is built up and the movable valve grid 94 moves forward to close the openings in the fixed grid 93 and withdraw the plugs 92 from the nozzles 91, at which time the arm 110 again engages the contact 113 and renders the spark-plugs 115 operative.

It will be understood that the auxiliary containers 102 are composed of inner and outer perforated portions as in the form previously described and that these portions have the same relative movement during the operation of the device. Springs 116 (Fig. 11) are provided for drawing the movable grid forward as the flow of air through the funnel 101 is decreased by the building up of pressure in the combustion chamber.

Having thus described my invention and the advantages thereof, I do not wish to be limited to the details herein disclosed, otherwise than as set forth in claims, but what I claim is:—

1. Propulsion apparatus comprising a combustion chamber, an outwardly expanding discharge nozzle connected thereto, means to admit a fuel mixture to said chamber, means to close said nozzle until said chamber is filled by a fuel mixture to a predetermined pressure, and means to open said nozzle and thereupon fire said fuel mixture when such pressure is attained.

2. The combination in propulsion apparatus as set forth in claim 1, in which means is provided effective to furnish a relatively richer mixture toward the discharge end of said chamber.

3. The combination in propulsion apparatus as set forth in claim 1, in which auxiliary fuel containers are provided within said combustion chamber and in which means is provided for filling said auxiliary containers with a fuel mixture of greater average richness.

4. The combination in propulsion apparatus as set forth in claim 1, in which auxiliary fuel containers are provided within said combustion chamber and in which means is provided for filling said auxiliary containers with a relatively rich mixture throughout their length.

5. The combination in propulsion apparatus as set forth in claim 1, in which auxiliary fuel containers are provided within said combustion chamber and in which means is provided for establishing open communication between said chamber and said container as the fuel mixture is fired.

6. The combination in propulsion apparatus

as set forth in claim 1, in which auxiliary fuel containers are provided within said combustion chamber and in which means is provided for admitting fuel to said combustion chamber for a relatively short period of time and for admitting fuel to said auxiliary containers for a relatively longer period of time.

7. Propulsion apparatus comprising a combustion chamber, an outwardly expanding discharge nozzle connected to one end thereof, a plurality of valve members mounted at the opposite end of said chamber for admitting a fuel mixture thereto, means to simultaneously open said valve members and close said discharge nozzle and vice-versa, and means to fire the fuel mixture in said chamber when said valve members are closed and said nozzle is open.

8. The combination in propulsion apparatus as set forth in claim 7, in which each valve member comprises a fixed and a movable portion.

9. The combination in propulsion apparatus as set forth in claim 7, in which each valve member comprises a fixed and a movable portion, said portions together forming a stream line structure when said valve is opened to admit a fuel mixture.

10. The combination in propulsion apparatus as set forth in claim 7, in which each valve member comprises a fixed and a movable portion, said fixed portion having fuel passages extending throughout their length, spray openings communicating with said passages, and means to control the flow of fuel to said spray openings.

11. The combination in propulsion apparatus as set forth in claim 7, in which each valve member comprises a fixed and a movable portion, said fixed portions having fuel passages extending throughout their length, spray openings communicating with said passages, means to admit fuel to said spray openings as the movable valve portions open, thereby admitting a fuel mixture to the combustion chamber, and to shut off the fuel supply to said spray openings as said valve portions reach fully open position.

12. Propulsion apparatus comprising a combustion chamber, auxiliary fuel containers each formed of inner and outer perforated sleeves, and means to fire the fuel mixture in said chamber and to align the perforations in the inner and outer sleeves when said mixture is fired.

13. Propulsion apparatus comprising a combustion chamber, a discharge nozzle therefor, means to fill said chamber with a fuel mixture decreasing in richness from the discharge end of said chamber forward, and means to consume said fuel progressively from the discharge end.

14. Propulsion apparatus comprising a combustion chamber, a gas discharge nozzle connected to the rear end of said chamber valve members at the front of said chamber controlling admission of air and fuel thereto, said valve members comprising fixed portions spaced apart and movable portions which may be positioned in streamline alignment with said fixed portions or positioned at an angle thereto in which they close the spaces between the fixed portions, and means to move said movable valve portions.

15. The combination in propulsion apparatus as set forth in claim 14, in which a funnel is connected to the front end of said combustion chamber, and in which the valve-moving means is responsive to the relative air pressures in said chamber and in said funnel respectively.

16. The combination in propulsion apparatus as set forth in claim 14, in which a funnel is connected to the front end of said combustion chamber, and in which means is provided to close the valve members and fire the fuel mixture as the air pressures in said chamber and in said funnel becomes substantially equalized.

17. Propulsion apparatus comprising a combustion chamber, a gas discharge nozzle connected to the rear end of said chamber, valve members at the front of said chamber controlling admission of air and fuel thereto, said valve members comprising fixed portions spaced apart in the form of a grid, movable portions spaced apart and forming a second grid, and means to move said second grid axially toward and from said first grid to close or open said valves in accordance with the relative air pressures forward and rearward of said valve members.

18. The combination in propulsion apparatus as set forth in claim 17, in which fuel-admitting valves are connected to said movable valve grid so that they are opened during rearward movement only thereof, said fuel-admitting valves closing as the rearward movement of said movable valve grid is completed.

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