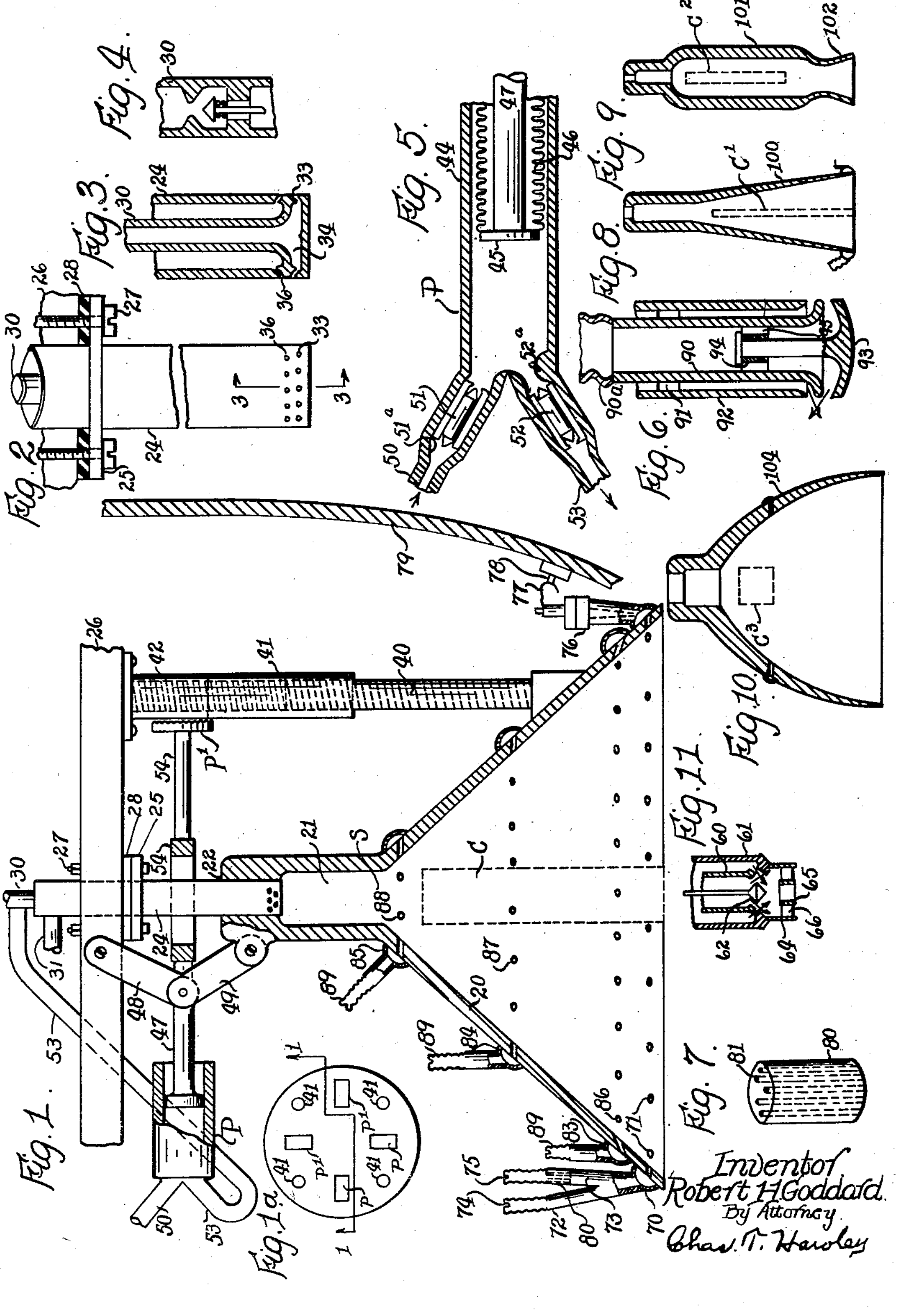
March 29, 1949. R. H. GODDARD 2,465,525

REACTION COMBUSTION CHAMBER FOR UNCONFINED CHARGES
OF DETONATIVE FUEL FED INTERMITTENTLY
TO THE COMBUSTION CHAMBER

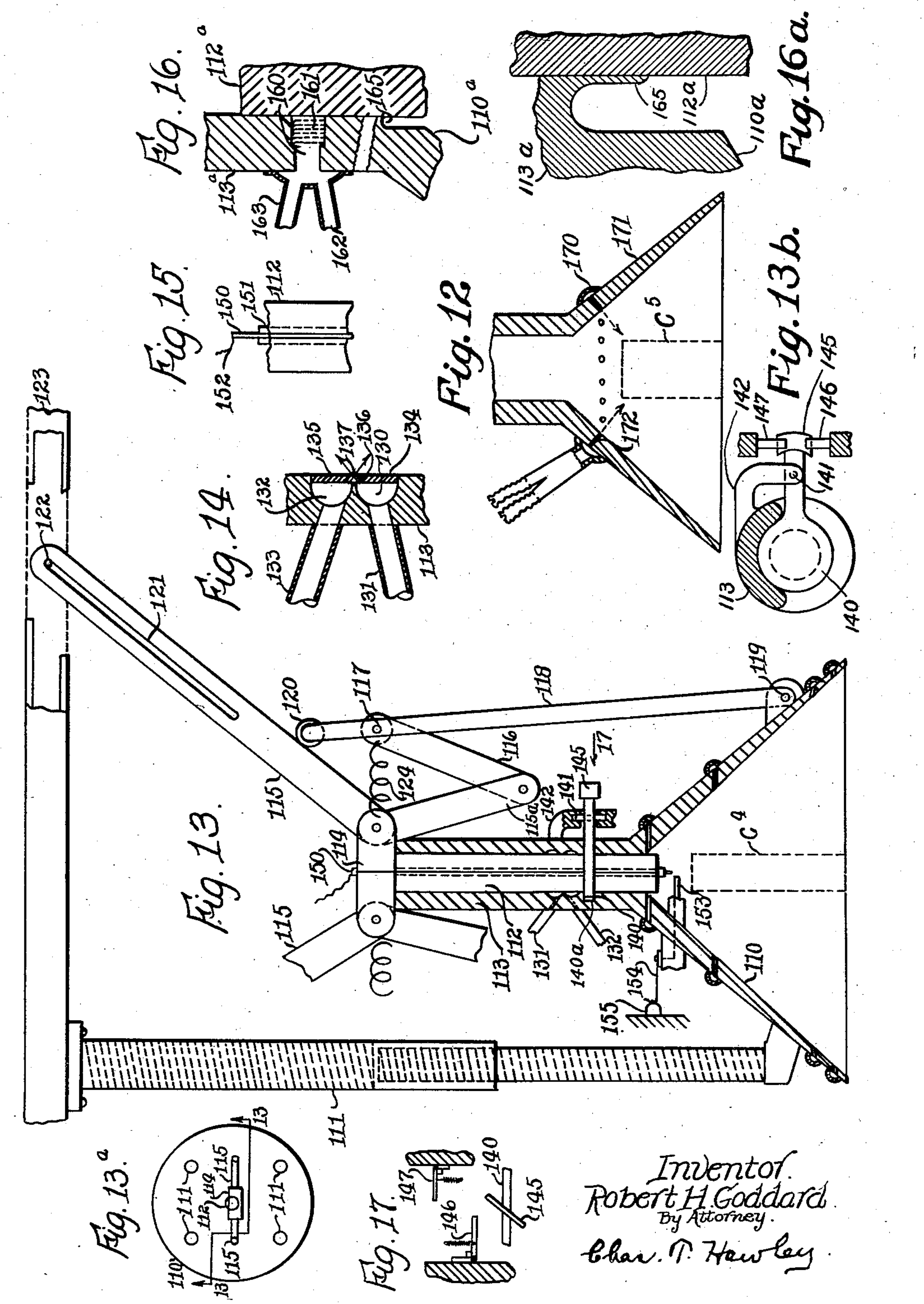
Filed Dec. 15, 1943 2 Sheets-Sheet 1



March 29, 1949. R. H. GODDARD 2,465,525

REACTION COMBUSTION CHAMBER FOR UNCONFINED CHARGES OF DETONATIVE FUEL FED INTERMITTENTLY TO THE COMBUSTION CHAMBER

Filed Dec. 15, 1943 2 Sheets-Sheet 2



Inventor.
Robert H. Goddard.
By Attorney.
Chas. P. Hawley

Patented Mar. 29, 1949

2,465,525

UNITED STATES PATENT OFFICE

2,465,525

REACTION COMBUSTION CHAMBER FOR UNCONFINED CHARGES OF DETONATIVE FUEL FED INTERMITTENTLY TO THE COMBUSTION CHAMBER

Robert H. Goddard, Annapolis, Md.; Esther C. Goddard, executrix of said Robert H. Goddard, deceased, assignor of one-half to The Daniel and Florence Guggenheim Foundation, New York, N. Y., a corporation of New York

Application December 15, 1943, Serial No. 514,411

14 Claims. (Cl. 60—35.6)

1

This invention relates to combustion chambers of the type in which a mixture of combustible and oxidizing liquids is consumed. More specifically, the invention relates to a combustion chamber of the general type shown in my prior application Serial No. 273,600, now Patent No. 2,396,566, issued March 12, 1946, in which the fuel charge is spaced from all supporting or confining surfaces at the instant of ignition and during combustion or detonation thereof.

It is the general object of my present invention to improve and simplify the construction shown in my prior application by presenting successive unconfined plugs or short columns of mixed combustible and oxidizing liquids to the combustion chamber, in place of using cartridges as in said prior application. I thus avoid provision of any cartridge magazine or of the multiplied feeding devices disclosed in said application.

A further object of the present invention is to provide improved and simplified devices for feeding the liquids to the combustion chamber in successive small amounts by utilizing the recoil of the combustion chamber caused by each detonation therein.

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

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

Fig. 1 is a sectional front elevation of one form of my improved combustion chamber, the section being taken along the irregular line 1—1 in Fig. 1*a*;

Fig. 1*a* is a diagrammatic plan view, showing the section on which Fig. 1 is taken;

Fig. 2 is an enlarged front elevation of an injector shown in Fig. 1;

Fig. 3 is a partial sectional elevation of the injector, taken along the line 3—3 in Fig. 2;

Fig. 4 is a detail sectional view of a one-way control valve to be described;

Fig. 5 is a sectional side elevation of a pressure pump;

Fig. 6 is a view similar to Fig. 3 but showing a modified injector construction;

Fig. 7 is a perspective view of a perforated plug to be described;

Figs. 8, 9 and 10 are sectional front elevations of modified combustion chambers;

Fig. 11 is a partial sectional elevation of a further modification of the injector;

Fig. 12 is a sectional elevation of a combustion chamber modified for short and relatively thick fuel columns or plugs;

2

Fig. 13 is a sectional elevation of a modified combustion apparatus in which the stationary injector is replaced by a reciprocating post or piston, taken along the line 13—13 in Fig. 13*a*;

Fig. 13*a* is a diagrammatic plan view showing the section on which Fig. 13 is taken;

Fig. 13*b* is a plan view, partly in section, of certain parts shown in Figs. 13 and 17;

Fig. 14 is an enlarged sectional elevation of certain feeding devices to be described;

Fig. 15 is a partial sectional elevation of the reciprocated post;

Fig. 16 is a sectional elevation of a modification of the feeding devices shown in Fig. 14;

Fig. 16*a* is an enlarged sectional view of a portion of Fig. 16; and

Fig. 17 is a detail view of certain disc-operating mechanism to be described.

Referring to Figs. 1 to 5, I have shown a combustion chamber 20 in the form of a 90° cone, open at its lower end and having an upward extension providing a recess 21 and a hub or bearing portion 22. The walls of the chamber 20 are preferably thickened upwardly for increased strength.

The hub or bearing 22 is a close sliding fit on a cylindrical injector 24 (Fig. 2) having a flange 25 secured to a stationary support or cross bar 26 by clamping screws 27. A cushioning ring 28 of rubber or some similar material provides a yielding mounting for the injector.

Liquid fuel such as methane or propane is fed to the injector tube 24 through a pipe 30 (Fig. 1), and a liquid oxidizing agent such as liquid oxygen is fed to the injector through a pipe 31 connected to the annular space between the pipe 30 and the wall of the injector. The liquids may be supplied to the pipes 30 and 31 through suitable connections from pressure tanks (not shown) or by pumping devices P to be described.

The injector tube 24 is provided with a series of openings or feed orifices 33 (Figs. 2 and 3) connecting through a recess 34 to the fuel supply pipe 30, and with an additional series of feed orifices 36 connecting into the annular space between the pipe 30 and the injector tube 24. The combustion liquids are thus injected into the recess 21 (Fig. 1) at the upper end of the chamber 20 whenever the orifices 33 and 36 are uncovered by upward movement of the chamber 20 and its hub or bearing portion 22 relative to the injector.

The chamber 20 is provided with a plurality of hollow posts 40 extending upwardly and telescoping in sleeves or cylinders 41 depending from the fixed support 26. A coil spring 42 is held under compression in each hollow post 40 and cylinder 41 and these parts are mounted in diametrically spaced pairs, as clearly shown in Fig. 1*a*. The springs 42 yieldingly resist upward or recoil movement of the chamber 20, and correspondingly assist the return or downward movement thereof.

Preferably the posts 40 are reasonably close sliding fits in the cylinder 41, so that a body of air is trapped inside of the posts and cylinders and is compressed as the posts 40 are moved upward, thus providing an air cushion acting in conjunction with each compression spring 42.

As the cylinder 20 is forced upward by the recoil, the holes 33 and 36 are uncovered and the two liquids are sprayed into the recess 21 through the orifices 33 and 36 and are intimately mixed therein. The column of mixed liquids thus formed will then move downward out of the recess 21 to the position indicated at C in Fig. 1, leaving a space S above the column which is substantially free of the detonating mixture.

This is desirable, as the mixture is thereby spaced from the upper end of the chamber wall and gases and vapors in the space S provide a cushion which protects the lower end of the projector 24 from the full force of the detonation.

While the liquids may be fed to the pipes 30 and 31 by constant pressure from pressure tanks as above described, it is sometimes desirable to provide an intermittent or pulsating pressure, which pressure is applied when the feed orifices 33 and 36 are open but relieved when the orifices are closed.

For this purpose, I provide pairs of pumps P and P' (Figs. 1 and 1*a*). Each of these pumps consists of a hollow cylinder 44 (Fig. 5) having a piston 45 connected to the open outer end of the cylinder 44 by a bellows member 46. The piston rod 47 for the piston 45 is connected to a pair of toggle links 48 and 49 (Fig. 1). The link 48 is pivoted at its upper end to the fixed support 26 and the link 49 is pivoted at its lower end to the hub portion 22 of the combustion chamber 20. As the combustion chamber rises, the toggle links will be swung outward and the piston 45 will be moved to the left in Fig. 5, while downward movement of the combustion chamber will cause a corresponding return movement of the piston to the right.

As the chamber 20 descends and the piston 45 moves to the right, one of the liquids, as liquid fuel, will be drawn in from a supply pipe 50 past a bobbin-type check valve 51 slidable below a seat portion 51*a* of reduced diameter. On the next upward or recoil movement of the chamber 20, movement of the piston 45 to the left will force the liquid fuel out past a check valve 52, slidable below a seat portion 52*a* of reduced diameter to a pipe 53 which may be connected with the injector feed pipe 30. An oppositely positioned pump P' will be similarly connected to a supply of the second liquid, as liquid oxygen, and to the other feed or supply tube 31 for the injector 24.

The piston rod 54 (Fig. 1) for the pump P' is preferably connected to the piston rod 47 for the associated pump P by a yoke 54 spanning the injector 24 so that the pumps P and P' of each pair feed alternately. Two pumps P are commonly used to supply the liquid fuel and two other pumps P' to supply the liquid oxygen. One pump P and one pump P' feed on each recoil, so that pumping is substantially continuous except at the end of the return stroke when the links 48 and 49 are nearly in line and produce little piston movement. At this interval of lower pressure the feed openings are covered and firing takes place.

A modified construction of injector is shown in Fig. 11, in which an inner tube 60 and outer tube 61 supply annular sprays of liquid fuel and liquid oxygen through narrow annular slots formed at their lower ends by a spreader 62. The mixture thus formed is then discharged downward through a short tube 64 having a guide or directing ring 65 mounted therein on spaced webs or arms 66. This construction has the advantage of end delivery from the injector instead of side delivery, which in turn permits the outer tube 61 to have a sliding fit in the recess 21 as well as in the hub portion 22 of the combustion chamber 20. The flow of the liquids to the combustion chamber is also more direct.

For igniting the charge C in the conical combustion chamber 20, I provide an annular casing 70 (Fig. 1) surrounding the larger and open end of the chamber 20 and connected with the chamber by a plurality of perforations 71, spaced about the periphery of the chamber. A feed pipe 72 for liquid oxygen and a feed pipe 73 for liquid fuel are jointly connected at their lower ends to the annular casing 70 and are connected at their upper ends by flexible tubes 74 to suitable supplies (not shown) of liquid oxygen and liquid fuel under constant pressure.

A spark-plug 76 is mounted on the casing 70 and is provided with a yielding contact arm 77 which engages a contact stud 78 as the combustion chamber 20 reaches its lowest position. The stud 78 may be mounted in fixed position on the casing 79 of a rocket craft or on other fixed structure in which the combustion chamber is mounted.

In order to prevent the formation of an explosive mixture in the liquid fuel feed pipe, I preferably provide a plug 80 (Fig. 7) in the feed pipe 73 (Fig. 1) and form this plug with a plurality of small longitudinal perforations 81. With this construction, flow of liquid fuel through the plug 80 may take place rapidly enough for ignition purposes, but reverse flow against pressure will be greatly retarded and substantially prevented.

In order to cool the inner surface of the combustion chamber 20, I provide a plurality of annular casings 83, 84 and 85, mounted in axially spaced relation on the outer surface of the combustion chamber and connected with the interior thereof by perforations 86, 87 and 88. The perforations 87 and 88 are preferably approximately tangential to the cone in planes normal to its axis, and the perforations 86 are similarly tangential and also inclined upwardly as viewed in Fig. 1.

The casings 83, 84 and 85 have suitable flexible connections 89 to a supply of water under pressure. The water is thus injected through the perforations 86, 87 and 88 to provide a liquid film on the inner surface of the combustion chamber and to thereby prevent overheating of the chamber wall.

A further modification of the injector is shown in Fig. 6, in which the inner tube 90 is slidably mounted in spaced guides 91 in the outer tube 92 and in which an end plate 93 is slidably mounted in a bearing 94 secured on spaced arms 95 in the tube 90. A flexible connection 90*a* is provided at the upper end of the tube 90 to permit slight endwise movement thereof.

With this construction, the combustion liquids are injected through closely adjacent annular slots in the outer cylindrical surface of the injector, and the slots are closed by upward movement of the plate 93 and inner tube 90 whenever a charge is detonated, thus preventing back pressure in the tubes 90 and 92.

In Figs. 8, 9 and 10 I have shown certain modifications in the cross-section of the combustion chamber and in the shape and size of the charge to be detonated. The section shown in Fig. 1 is desirable for a charge which detonates with great rapidity and which produces a large mass of combustion gases substantially instantaneously.

For a charge C' (Fig. 8) which detonates at a relatively slow rate, an elongated combustion chamber 100 having a narrow angle of expansion is desirable. For a charge C2 (Fig. 9) of mixed liquids which explode rather than detonate, a cylindrical combustion chamber 101 having a discharge nozzle 102 is desirable.

A chamber 104 (Fig. 10) of parabolic section may be used for a relatively short and thick charge C3. Such a charge has the advantage of retaining its cylindrical form more perfectly and also has a reduced rate of evaporation. The force of the detonation, however, is more largely exerted against the upper part of the chamber, which necessitates further thickening of its side wall.

In Figs. 13 to 16, I have shown a modified construction in which a combustion chamber 110 is mounted to move vertically on telescoping supports 111 which may be of the same construction and operation as the corresponding parts shown in Fig. 1.

A plunger 112 is mounted to slide vertically in a hub or extension 113 of the combustion chamber 110. At its upper end the plunger 112 has a cross head 114 to which is pivoted a pair of levers 115. Each lever 115 is pivoted at its lower end 115*a* to a link 116, the upper end of which is pivotally connected at 117 to an arm 118 pivoted at its lower end at 119 to a lug on the combustion chamber 110.

The upper end of each arm 118 coacts with one of the levers 115. Each lever 115 is provided with an elongated slot 121 through which extends a pin 122 mounted in a fixed support 123. A tension spring 124 draws the arm 118 toward the axis of the combustion chamber. Exactly similar structure is provided at the left in Fig. 13 but is omitted for the sake of clearness, the section being taken on a line corresponding to the line 13—13 in Fig. 13*a*

An annular recess 130 (Fig. 14) is formed in the extension 113 of the combustion chamber, and an oxygen feed pipe 131 is connected to said recess. A similar, closely adjacent recess 132 is also provided, connected with a liquid fuel feed pipe 133. These recesses are closed on the inside by annular rings or webs 134 and 135, having adjacent slotted openings 136 and 137, constituting intersecting delivery passages through which streams of the combustile liquids may enter the recess in the hub or extension 113 when the plunger 112 is raised. The provision for ignition of the charge and cooling of the chamber walls may be the same as previously described in connection with Fig. 1.

With this construction, upward movement of the chamber 110 on detonation of a charge not only carries the plunger head 114 bodily upward but also gives the levers 115 combined swinging and sliding movements about the fixed pins 122. This results in moving the head 114 and plunger 112 upward substantially faster than the cylinder 110 and hub 113. The supply pipes 131 and 132 are maintained under constant pressure, or may be connected to intermittently acting pressure pumps as shown in Fig. 1.

Whenever the plunger 112 is thus raised at double speed, the annular port 134 is opened and the combustion liquids flow into the cylindrical recess in the hub 113. As the chamber 110 thereafter moves downward and returns to initial position, the plunger 112 simultaneously moves downward at twice the speed of the chamber and thus transfers the charge from the recess in the hub 113 to the operative position in the chamber 110 indicated at C4.

It is desirable that the lower end of the recess in the hub 113 be closed during admission of the combustible liquids thereto, so that the liquids may be well mixed within the recess before being transferred to the chamber 110.

For this purpose, I provide a disc 140 (Figs. 13 and 13*a*) mounted to swing in a horizontal slot or opening 140*a* (Fig. 13) in the hub 113 and pivoted on a stud 141 mounted in brackets 142 carried by the hub 113. A cam plate 145 (Figs. 13*a* and 17) is mounted on an outward extension of the disc 140 and is engageable by a stop 146 as the chamber 110 moves upward and by a stop 147 as the chamber thereafter moves downward. The stops 146 and 147 are yieldingly mounted on stationary parts of the mechanism, so that the stop 147 yields upwardly and is inoperative as the cam plate 145 moves upward, and the stop 146 is correspondingly yielding downwardly and inoperative as the cam plate moves downward.

Fixed abutments (Fig. 17) prevent movement of the stop 146 upward and the stop 147 downward from normal position.

Consequently, as the chamber moves upward, the stop 146 will swing the disc 140 to closed position and on the next downward movement the stop 147 will swing the disc to open position.

Ignition may take place as previously described in connection with Fig. 1, or the charge may be ignited at its upper end by extending a rod 150 (Fig. 15) axially through the plunger 112 and insulating the rod by a bushing 151. One wire 152 of an ignition circuit is secured to the upper end of the rod 150 and contact is made with the other spark terminal 153 through a spring contact 154 and fixed stud 155, thus completing the ignition circuit when the combustion chamber reaches its lowest position.

In Fig. 16 I have shown a modified construction for feeding the liquids to a recess 160 in the hub 113*a* of a combustion chamber 110*a*. In this construction, the recess 130 (Fig. 14) is replaced by the annular recess 160 in which wire mesh cloth or its equivalent is coiled in layers 161. With this construction, the liquids become intimately intermingled as they pass through the wire wesh layers 161, and the screen also prevents burning gases from reaching the supply pipes 162 and 163. A downwardly projecting flange 165 (Fig. 16*a*) at the lower end of the hub 113*a* helps to prevent upward leakage of the combustion gases past the piston or plunger 112*a*. The wire mesh layers may be replaced with perforated plates having their openings out of alignment.

In Fig. 12, I have shown a further modification in which an ignition ring 170 is mounted near the upper end of the combustion chamber and the injection openings 172 are made perpendicular to the conical inner face of the combustion chamber and are directed toward the upper end of the charge C5, as indicated by the arrows. With the passages 172 thus positioned, the ignition flames traverse the shortest distance to contact the charge and the charge is ignited at its upper end instead of at its lower end. The possibility of disturbance of the ignition flame by external air currents is reduced with this construction.

Provision for igniting the mixed liquids in the annular ring 170 may be the same as shown for the ring 70 in Fig. 1 but these parts do not appear in the section on which Fig. 12 is taken.

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 the claims, but what I claim is:

1. In an apparatus for producing a propulsive force by the reaction obtained from the detonation of successive charges of fuel and an oxidizing agent, in combination, a combustion chamber permanently open at its lower discharge end, said chamber being supported for upward movement under recoil, means controlled by said movement and return, effective to place successive unconfined unitary detonating charges of previously intermingled combustion liquids in a firing position within said chamber, which position is spaced from the chamber walls, and means to ignite and instantaneously detonate each charge when thus positioned, the diameter of each charge being a minor fraction of the average effective diameter of the combustion chamber.

2. In an apparatus for producing propulsive force by the reaction obtained from the detonation of successive charges of fuel and an oxidizing agent, in combination, an injector for combustion liquids, a combustion chamber permanently open at its lower discharge end and mounted to slide axially on said injector and to be moved relative thereto by recoil following ignition of a charge therein, means to supply combustion liquids under pressure through feed openings in said injector to said combustion chamber, said openings being normally closed and being uncovered when the chamber recoils, said liquids intermingling in the upper part of said chamber to form a detonating charge and being advanced as successive unconfined unitary and previously intermingled detonating charges to a firing position within said chamber, which position is spaced from the chamber walls, and means to ignite and instantaneously detonate each charge thus positioned, the diameter of each charge being a minor fraction of the average effective diameter of the combustion chamber.

3. In an apparatus for producing propulsive force by the reaction obtained from the detonation of successive charges of fuel and an oxidizing agent, in combination, an injector for combustion liquids, a combustion chamber, permanently open at its lower discharge end and mounted to slide axially on said injector and to be moved relative thereto by recoil following ignition of a charge therein, said injector having feed openings therein which are covered and closed by said chamber when in initial lower position and which are uncovered and opened by upward recoil displacement of said chamber, means to supply combustion liquids under pressure through said feed openings in said injector to said combustion chamber when the chamber recoils upward, said liquids intermingling in the upper part of said chamber to form a detonating charge and being advanced as successive unconfined unitary and previously intermingled detonating charges to a firing position within said chamber, which position is spaced from the chamber walls, and means to ignite and instantaneously detonating each charge thus positioned as said chamber completes its return movement.

4. In an apparatus for producing propulsive force by the reaction obtained from the detonation of successive charges of fuel and an oxidizing agent, in combination, a tubular injector mounted in fixed position, a conical open-ended combustion chamber having a reduced entrance portion and mounted to slide axially on said injector by recoil of said chamber on detonation of a charge therein, springs to yieldingly resist such recoil movement and to effect return of said injector to initial position, said injector having feed openings uncovered by said reduced entrance portion of said chamber on recoil movement and covered by return movement thereof, means to supply combustion liquids through said feed openings to said reduced entrance portion of said chamber for intermingling therein to form a detonating charge when said openings are uncovered, and means to ignite and instantaneously detonate the previously intermingled liquids in said chamber on return of said chamber to initial position.

5. The combination in propulsion apparatus as set forth in claim 4, in which separate pressure pumps are provided for each liquid and in which said combination includes connections between said pumps and said chamber effective to operate said pumps in pairs by the recoil and return movements of said chamber.

6. The combination in propulsion apparatus as set forth in claim 4, in which said chamber includes means to cool the inner conical surface of said combustion chamber in a plurality of axially-spaced zones.

7. The combination in propulsion apparatus as set forth in claim 4, in which separate pressure pumps are provided for each liquid and in which said combination includes connections between said pumps and said chamber effective to operate said pumps in pairs by the recoil and return movements of said chamber, certain of said pumps delivering liquid on recoil of said chamber and certain other pumps delivering liquid on return movement of said chamber.

8. The combination in propulsion apparatus as set forth in claim 4, in which said combination includes means to feed additional combustion liquids under pressure to an annular passage disposed about the discharge end of the conical combustion chamber, said passage being connected to said chamber by relatively small spaced openings, and in which said combination includes means to periodically ignite said intermingled liquids.

9. The combination in propulsion apparatus as set forth in claim 4, in which said combination includes means to feed additional combustion liquids under pressure to an annular passage disposed about the discharge end of the conical combustion chamber, said passage being connected to said chamber by relatively small spaced openings, together with means to periodically ignite said intermingled liquids, and in which said combination includes a device to prevent backfire in the fuel connections to said annular passage.

10. In an apparatus for producing propulsive force by the reaction obtained from the detonation of successive charges of fuel and an oxidizing agent, in combination, a combustion chamber mounted for recoil and return movement and having an elongated hub portion, a post on which said hub is slidable, means to move said post on recoil of said chamber at greater speed than said chamber but simultaneously therewith in the same direction, thereby withdrawing said post on recoil, means to feed combustion liquids through said hub to said chamber when said feeding means is uncovered by withdrawing movement of said post on recoil of said chamber, said liquids intermingling in said chamber to form a detonating charge, and means to ignite and instantaneously detonate said intermingled liquids.

11. The combination in propulsion apparatus as set forth in claim 10, in which said combination includes multiplying linkage which connects said chamber to said post and which moves said post simultaneously with said chamber and substantially faster in the same direction.

12. The combination in propulsion apparatus as set forth in claim 10, in which said combination includes a disc in said elongated hub, together with means to close said disc as said post is withdrawn from said hub and to open said disc as said post moves into said hub.

13. The combination in propulsion apparatus as set forth in claim 10, in which the hub is provided with an annular recess to receive each of the combustion liquids, and in which said combination includes means to make delivery from said recesses to the interior of said hub as said post is withdrawn and uncover said recesses.

14. The combination in propulsion apparatus as set forth in claim 10, in which the hub is provided with an annular recess to receive the combustion liquids, and in which said combination includes means to make delivery from said recess to the interior of said hub as said post is withdrawn and uncovers said recess, and in which said combination includes substantially concentric layers of perforated material in said annular recess to prevent back-fire and to assist intermingling of said liquids.

ROBERT H. GODDARD.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
502,168	Battey	July 25, 1893
704,456	Gray	July 8, 1902
1,156,846	Johnson	Oct. 12, 1915
2,142,601	Bleecker	Jan. 3, 1939
2,283,863	Achterman	May 19, 1942

FOREIGN PATENTS

Number	Country	Date
3,561	Great Britain	Aug. 16, 1881
124,000	Germany	Oct. 14, 1901