

March 12, 1946.

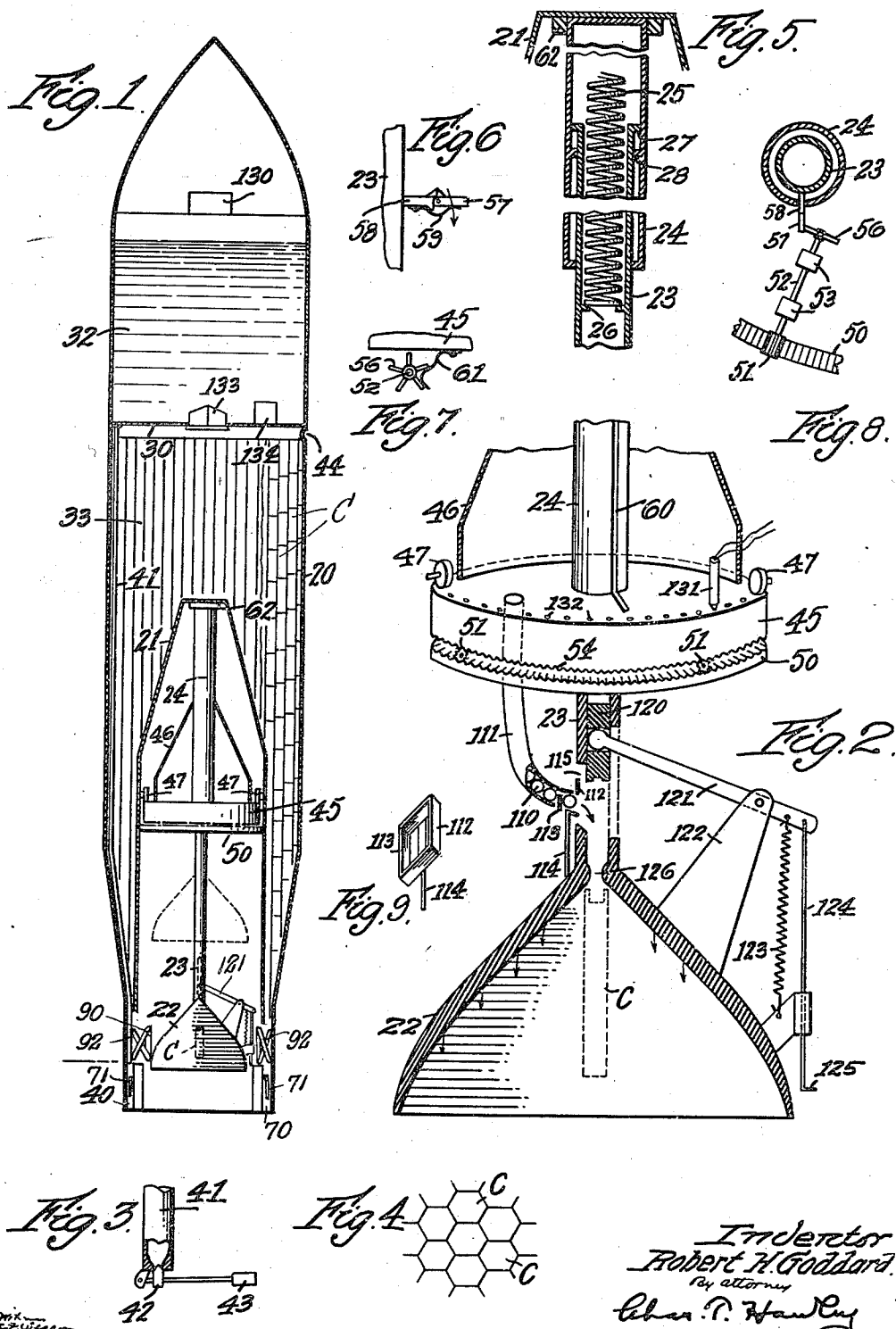
R. H. GODDARD

2,396,566

ROCKET APPARATUS

Filed May 15, 1939

4 Sheets-Sheet 1



Inventor
Robert H. Goddard
By attorney
Charles P. Hawley

March 12, 1946.

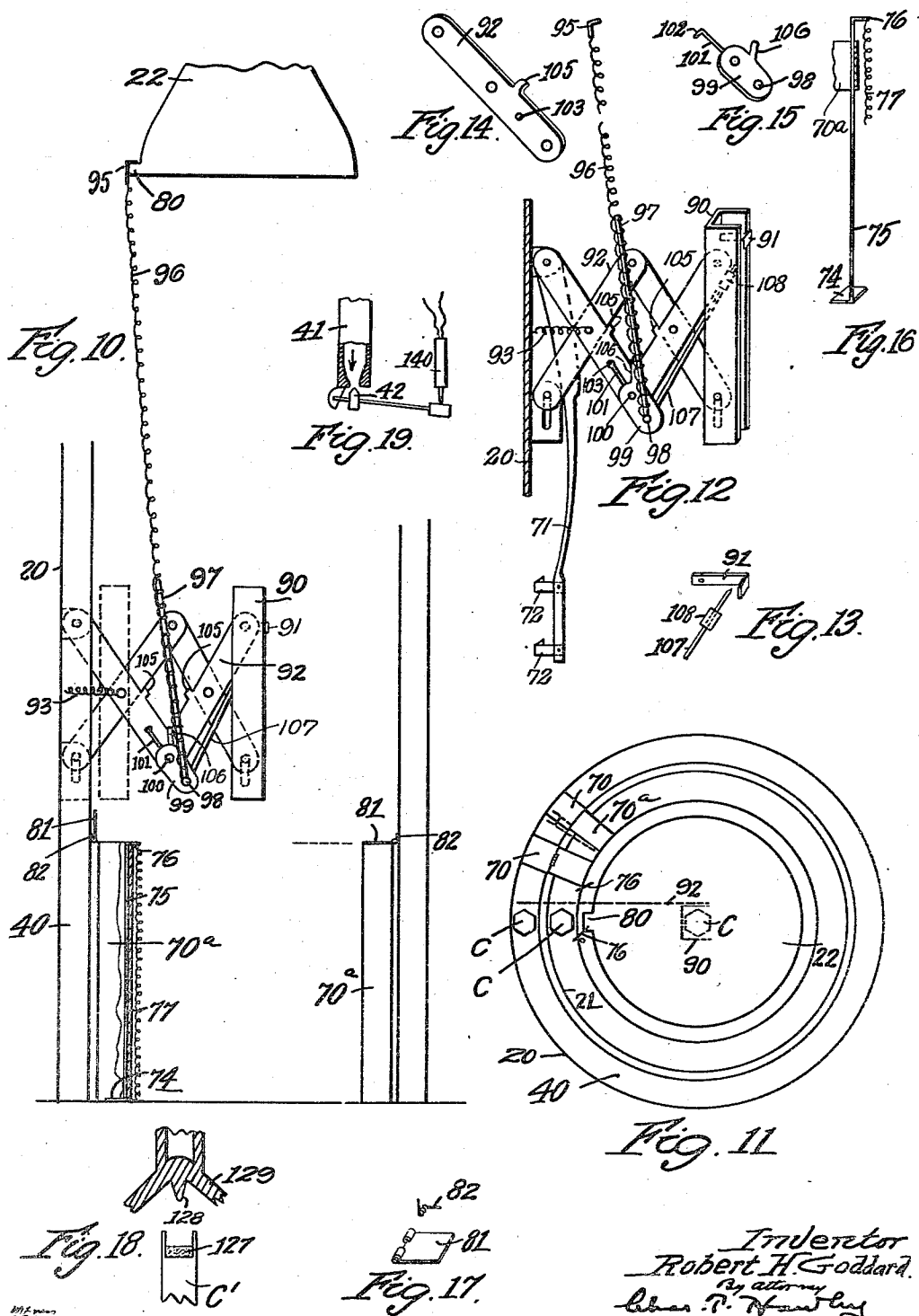
R. H. GODDARD

2,396,566

ROCKET APPARATUS

Filed May 15, 1939

4 Sheets-Sheet 2



March 12, 1946.

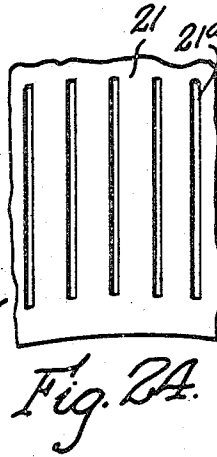
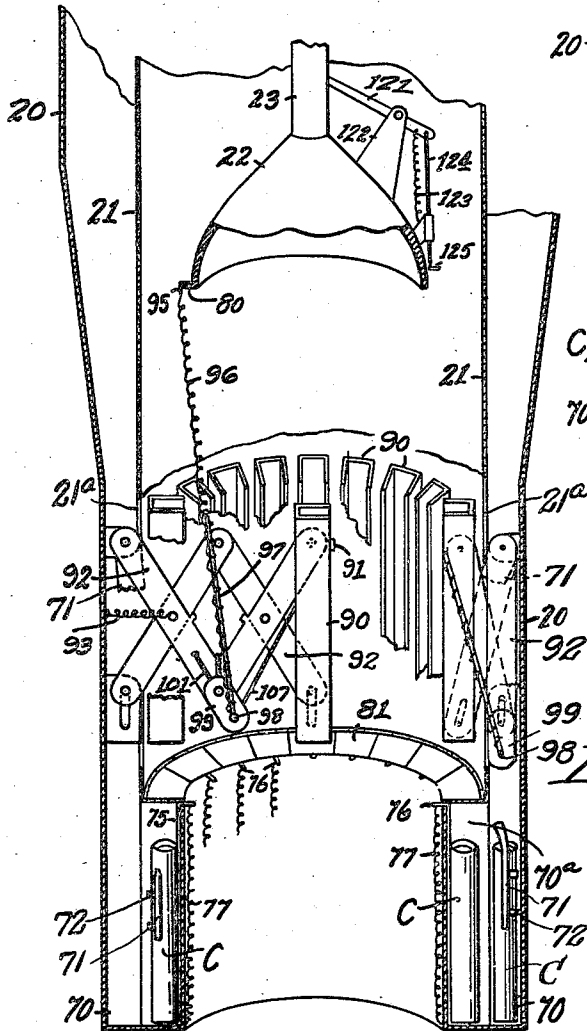
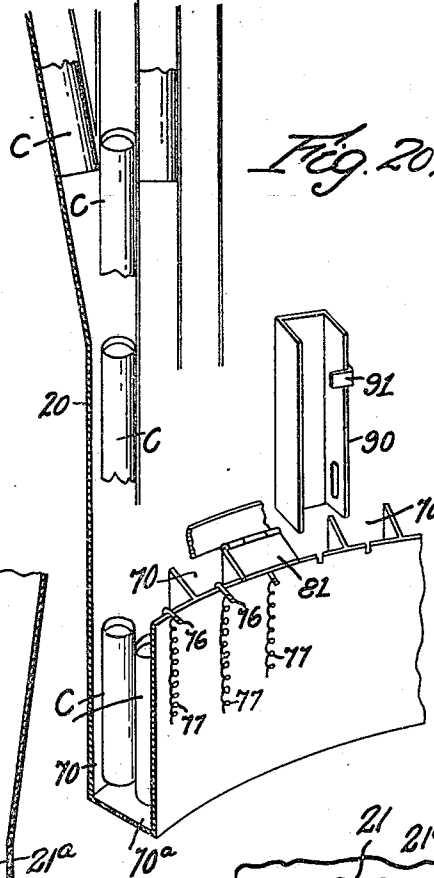
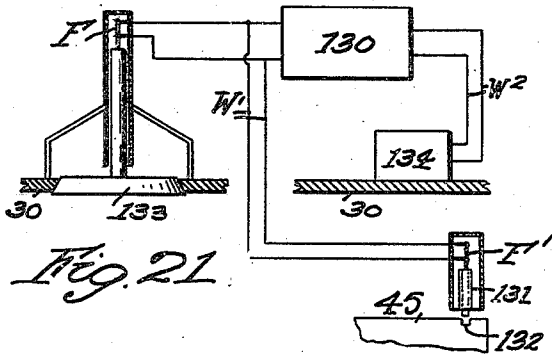
R. H. GODDARD

2,396,566

ROCKET APPARATUS

Filed May 15, 1939

4 Sheets-Sheet 3



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

March 12, 1946.

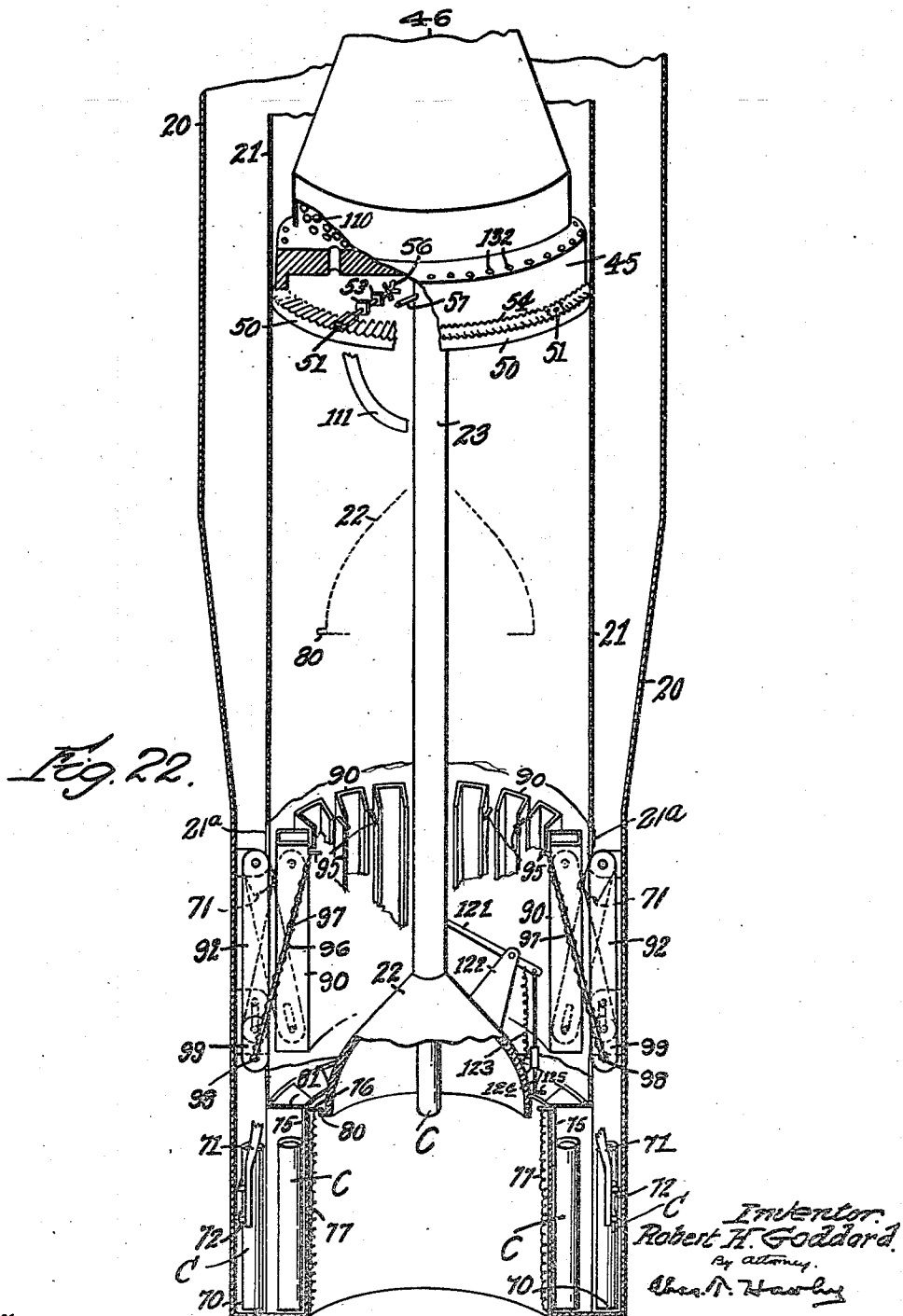
R. H. GODDARD

2,396,566

ROCKET APPARATUS

Filed May 15, 1939

4 Sheets-Sheet 4



UNITED STATES PATENT OFFICE

2,396,566

ROCKET APPARATUS

Robert H. Goddard, Roswell, N. Mex., assignor of one-half to The Daniel and Florence Guggenheim Foundation, New York, N. Y., a corporation of New York

Application May 15, 1939, Serial No. 273,600

12 Claims. (Cl. 102—34.5)

This invention relates to rocket apparatus adapted for purposes of high altitude research and propelled by ignition of successive charges of detonating or explosive material.

One important object of my invention is to provide a rocket in which said detonating or explosive material is ignited in a relatively unconfined condition, whereby excessive pressure and over-heating in the rocket are avoided.

A further object of my invention is to provide an improved type of nozzle having a reflecting surface so designed that gases approaching said surface from points within the nozzle will be reflected axially rearward of the apparatus and will thus exert a maximum propelling force thereon.

I also provide an improved form of cartridge, improved means for feeding successive cartridges to firing position, and novel means for successively igniting the cartridges thus positioned.

Briefly described, my improved rocket apparatus contemplates successive presentation and ignition of elongated detonating or explosive cartridges in axial but unconfined position within a nozzle having its inner end formed substantially as a 90° cone. The nozzle thus has the property of reflecting all of the explosion gases along rearward paths substantially parallel to the axis of the nozzle. As the explosive force of the gas is thus reflected rather than resisted, excessive pressure and strain are avoided and also objectionable heating of the reflecting surfaces.

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

A preferred form of the invention is shown in the drawings, in which:

Fig. 1 is a sectional side elevation of my improved rocket apparatus and with certain duplicated parts omitted for clearness;

Fig. 2 is an enlarged sectional view of certain parts shown in Fig. 1;

Fig. 3 is a detail view of a float valve to be described;

Fig. 4 is a diagrammatic view showing the method of nesting the cartridges;

Fig. 5 is a sectional side elevation of certain recoil mechanism;

Fig. 6 is a detail side view of a hinged feeding arm to be described;

Fig. 7 is a detail view of a star wheel and holding spring plate to be described;

Fig. 8 is a sectional plan view of certain parts shown in Fig. 2;

Fig. 9 is a perspective view of an escape device;

Fig. 10 is a side elevation of mechanism for advancing a cartridge to firing position;

Fig. 11 is a plan view of certain parts shown in Fig. 10;

Fig. 12 is a side elevation of a part of the cartridge-feeding mechanism;

Fig. 13 is a perspective view of parts of a cartridge-releasing device, also shown in Fig. 12;

Fig. 14 is a perspective view of one of the side plates shown in Fig. 12;

Fig. 15 is a perspective view of another part of the linkage shown in Fig. 12;

Fig. 16 is a perspective view of a cartridge-transfer rod;

Fig. 17 is an exploded view of a door and spring for a cartridge-soaking compartment;

Fig. 18 is a detail sectional elevation of a cartridge-firing device to be described;

Fig. 19 is a view similar to Fig. 3 but showing the float valve in an opened position;

Fig. 20 is a perspective view of the cartridge-soaking and feeding mechanism;

Fig. 21 is a wiring diagram for the load-dumping devices;

Fig. 22 is a partial sectional front elevation similar to Fig. 1 but on an enlarged scale and showing additional parts in their operative relation to the vertically reciprocating reflector and just prior to ignition of the cartridge, and with certain duplicated parts omitted for clearness,

Fig. 23 is a view similar to Fig. 22 but showing the parts with the reflector raised and the cartridge carrier advanced to present a fresh cartridge in firing position and also with certain duplicated parts omitted, and

Fig. 24 is a detail side elevation of a portion of the lower end of the fixed inner casing.

Referring to Figs. 1 and 2, my improved rocket apparatus comprises a fixed outer casing 20, a fixed inner casing 21, and a reflector 22 within which explosion or detonation of successive cartridges C takes place.

The reflector 22 is mounted at the lower end of a tube 23 which is slidable upward in an outer tube 24 (Fig. 5). A coil spring 25 is mounted between the upper end of the outer tube 24 and a flange 26 within the tube 23 and acts to move the reflector yielding to the normal rearward or lower position shown in full lines in Fig. 1. Cooperating flanges 27 and 28 (Fig. 5) limit such outward movement of the inner tube 23.

The reflector 22 is preferably of the general construction shown in Fig. 2, with its side wall increasing in thickness upwardly, and with the inner surface of the side wall forming a 90° cone

in its upper portion and a parabolic surface in its lower portion.

With this construction, gases produced by detonation or explosion within the upper part of the reflector 22 will travel radially outward until they engage the conical surface of the reflector, whereupon they will be reflected rearwardly and substantially parallel to the axis of the apparatus and will thus exert their forces of explosion and expansion to the greatest advantage and directly in the line of flight. Furthermore, as the cartridge C is at no point closely confined within the reflector, no excessive pressures are developed and overheating of the reflecting surface is also avoided.

The cartridges C may be of any suitable type but as shown herein they are preferably formed of a solid but porous material, such as carbon, which is thoroughly soaked in an oxidizing liquid, such as liquid oxygen, before being placed in the reflector 22 for explosion or detonation. This combination of solid and liquid elements is particularly effective, as the required proportions and intimate mixture of elements is easily attained and the cartridges are non-explosive in storage and until immersed.

For the storage and subsequent immersion of cartridges of the type described, I provide the rocket casing 20 with a partition 30 (Figs. 1 and 22) which provides an upper or tank portion 32 to contain an oxidizing liquid and a lower or magazine portion 33 in which a large number of cartridges may be stored. In order to utilize the magazine space to the greatest advantage, the cartridges C are preferably of the hexagonal cross section indicated in Fig. 4 and are closely nested in the magazine portion 33 of the rocket. A thin perforated casing may be provided for each cartridge, if desired, as shown in my prior Patent No. 1,341,053. The means for feeding the cartridges C from the different storage compartments in the magazine forms no part of my present invention but may be as shown and described in my prior Patent No. 1,103,503.

An annular trough 40 (Figs. 1 and 10) is provided near the rear or lower end of the rocket, which trough receives oxidizing liquid from the tank 32 through a supply pipe 41. This pipe is closed at its lower end by a valve 42 (Fig. 3) raised by a float 43 when the trough 40 contains a sufficient supply of liquid.

A small vent opening 44 (Fig. 1) in the upper part of the magazine 33 permits gases evaporating from the liquid in the trough 40 to pass upward through the magazine, thus pre-cooling the cartridges before they are delivered to the trough 40 for immersion.

The tube 24 is mounted on a disc 45 (Figs. 1 and 2) and is reinforced by a casing member 46 fixed at its upper end to the tube 24 and at its lower end to the disc 45. The disc 45 is engaged on its upper surface by a plurality of rollers 47 mounted on the inner surface of the fixed inner casing 21 and the disc is thus held from upward movement in the casing.

A circular rack 50 (Figs. 1 and 2) is mounted in the fixed inner casing 21 and is engaged by a plurality of pinions 51 (Fig. 8) mounted on short shafts 52 rotatable in bearings 53 secured to the under face of the disc 45. The pinions 51 also engage rack teeth 54 formed on the lower edge of the disc 45. The circular rack 50 and pinions 51 thus constitute supporting means for the disc 45 and the parts carried thereby, and

also provide means for intermittently rotating the disc 45, as will now be described.

One of the shafts 52 is provided with a star wheel 56 (Figs. 7 and 8) which is engaged by the pivoted outer end 57 of an arm 58 (Fig. 6) which is mounted on the inner tube 23 and travels vertically in a slot 60 (Fig. 2) in the outer tube 24. The arm 58 and slot 60 thus prevent relative angular movement between the tubes 23 and 24, while permitting free relative axial movement.

The arm 57 (Fig. 6) is free to swing downward on engagement of the star wheel 56 as the tube 23 moves upward, but is unyielding in the opposite direction, so that it engages and positively advances the star wheel 56 one space each time the tube 23 and reflector 22 move downward or rearward. A spring 59 (Fig. 6) holds the arm 57 yieldingly upward and a spring 61 (Fig. 7) yieldingly engages the star wheel 56 and prevents accidental rotation thereof. The upper end of the tube 24 abuts the under side of the fixed inner casing 21 and may be centered thereon by a bearing ring 62 (Fig. 5).

Each time that a cartridge C is exploded within the reflector 22, the reflector is forced upward or forward by recoil action against the spring 25, and on its return downward movement the arm 57 (Fig. 8) actuates the star wheel 56 and pinion 51 to angularly advance the gear 50, disc 45, casing member 46, tubes 24 and 23 and reflector 22 one space relative to the fixed outer casing 20 and fixed inner casing 21, for cartridge-feeding purposes to be described.

A plurality of magazine tubes or compartments 70 (Figs. 11 and 20) are provided between the fixed casing members 20 and 21, these compartments being spaced apart sufficiently to accommodate certain devices for successively presenting the cartridges in firing position.

The lowermost cartridge from each compartment 70 is immersed in the liquid in the trough 40 and remains so immersed during an entire revolution of the disc 45 and parts carried thereby. Each cartridge is then moved radially to an inner compartment 70^a by selective operating means and is then lifted above the compartment 70^a to the position indicated in dotted lines in Fig. 10, from which position it is advanced to axial alignment with the reflector 22 and the tubes 23 and 24.

Successive cartridges are moved inward by levers 71 (Fig. 12) each having a pair of hooks 72 adapted to extend behind a cartridge C and to move the cartridge to its compartment 70^a when the lever 71 is swung to the right as viewed in Fig. 12. The means for thus swinging the lever will be hereinafter described.

When in the compartment 70^a, the lower end of the cartridge rests on a plate 74 (Figs. 10 and 16) secured to the lower end of a thin rod 75 having an offset upper end or hook 76 and normally held downward by a spring 77.

The upper ends 76 of the rods 75 are successively engaged by a lug 80 (Fig. 11) on the outer edge of the reflector 22 as the reflector moves upward in recoil after each explosion. On the return stroke, the lug is advanced angularly with the reflector to engage another hook 76. A door 81 (Figs. 10 and 17) overlies each inner compartment 70^a and is held yieldingly closed by a spring 82. The door is lifted by the cartridge as the cartridge is raised and immediately closes after the raised cartridge has been moved radially inward. This prevents unnecessary evaporation of the

liquid oxygen and also prevents loss of liquid by tilting or jarring of the apparatus.

The offset end or hook 76 of the rod 75 slips off of the lug 80, due to the resilience of the rod, when the plate 74 reaches its extreme upper position and engages the upper end of the compartment 70^a. The spring 77 then returns the rod 75 and plate 74 to the position shown in Fig. 10.

When the cartridge is moved to its raised position, it is received in a carrier 90 (Fig. 12) which is open at its front side, except for a removable hook 91. Each carrier 90 is mounted on a plurality of side plates 92, pivotally supported on the fixed outer casing 20 and extending inward through a slot 21^a (Fig. 24) in the lower part of the fixed inner casing 21 and constituting a lazy-tongs structure of the usual type. A spring 93 acts to normally hold each carrier in withdrawn or outer position.

Each carrier is operated by engagement of the lug 80 on the reflector 22 with a hook 95 at the upper end of a spring 96 normally coiled on a rod 97 having its lower end pivoted at 98 on a plate 99 (Figs. 12 and 15).

The plate 99 is pivoted on the stud 100 which connects the pivoted ends of one pair of side plates 92, and is provided with a spring arm 101 (Fig. 15) having an offset end 102 projecting into an opening 103 in one of the arms 92. The spring 96 is thus yieldingly connected to actuate the lazy-tongs structure and advance the carrier 90 to the axial position indicated in full lines in Fig. 11, such movement being limited by stops 105 on certain plates 92 which engage abutting surfaces on other plates 92 when the carrier reaches axial position.

The plate 99 also has an offset arm 106 (Figs. 12 and 15) which slips into the V-shaped opening between two of the arms 92 as the carrier 90 reaches axial position. A rod 107 is pivoted to the outer end of the arm 99, and the upper end of the rod is guided at 108 to engage the hook 91 and remove the hook from holding position when the rod is forced upward.

The parts 90 to 107 are duplicated for each of the inner compartments 70^a arranged annularly within the casing 20. The reflector 22, however, has only a single lug 80 which will engage only one of the hooks 95 in any given position and which is intermittently advanced to successively engage the hooks.

By such engagement, the corresponding cartridge carrier 90 is advanced to axial position, where it is momentarily held stationary by the action of the lug 106 (Figs. 12 and 15). The reflector 22 continues to move upward and increasingly tensions the spring 96. When the spring 96 overcomes the spring 101, it turns the arm 99 anti-clockwise on its pivot 100, thus moving the rod 107 upward to displace the catch 91 clearly shown in Fig. 20.

As the reflector 22 thereafter moves downward, the spring 93 withdraws the carrier 90 but the cartridge C remains momentarily in its advanced position by reason of its own inertia. The reflector and cartridge then move downward to the position shown in Fig. 22, and on slight further downward movement the cartridge C is ignited. Although the cartridge remains unsupported during the final downward movement of the reflector the time interval is so short that no substantial displacement of the cartridge takes place.

The feeding arm 71 (Fig. 12) of the next compartment 70^a is mounted in fixed relation to one of the side plates 92^a in such manner that it

moves to the right in Fig. 12 as the carrier 90 is advanced to axial position. The arm 71 is long and very flexible, so as to allow for the extra swinging motion of the side plate 92^a and also to permit the hooks 72 to slip sideways behind a cartridge in the trough 40.

By the mechanism thus far described, a cartridge of porous carbon or similar material is soaked in liquid oxygen for one revolution of the disc 45, is thereupon advanced to its inner compartment 70^a by its associated feeding arm 71, is then raised to the dotted line position in Fig. 10 by its plate 74 and rod 75, is then advanced horizontally to axial position by its carrier 90 as shown in Fig. 11, and, after a momentary pause to overcome inertia, the cartridge is then released and the carrier is withdrawn, leaving the cartridge in axial position as the reflector 22 returns to its rearmost or firing position, as indicated in Fig. 2.

Means such as is disclosed in my prior Patent No. 1,103,503 may be provided to open up adjacent magazine tubes when certain tubes have been emptied.

I will now describe the provision which I have made for detonating or exploding the axially-positioned cartridge C.

The space within the casing member 46 and the disc 45 (Figs. 1 and 2) is utilized as a chamber or hopper for storage of a plurality of spherical percussion caps 110 which are fed downward through a pipe 111 and are retained therein by an escape device having stop plates 112 and 113 (Fig. 9).

As the reflector 22 moves upward, a rod 114 (Fig. 2) engages the escape device and moves it upward to the position shown in Fig. 2, in which position the plate 112 permits the lowermost cap to escape and enter the tube 23 through an opening 115 in the side thereof, while the other plate 113 prevents downward movement of the remaining caps.

A firing-pin 120 is slidable in the tube 23 and is actuated by a lever 121 pivoted on an arm 122 carried by the reflector 22. The firing-pin 120 is held yieldingly in raised position by a spring 123. A rod 124 is connected to the outer end of the lever 121 and is provided with an offset lower end 125 adapted to engage some fixed part of the magazine, such as one of the doors 81, when the reflector 22 descends.

Such engagement will force the firing-pin abruptly downward, thus exploding the cap 110 just above the restricted opening 126 at the lower end of the tube 23. The flash of the detonated cap 110 is directed to the top of the cartridge C through the opening 126 and instantly detonates or explodes the cartridge. The restriction of the tube 23 prevents premature escape of the released cap.

The upper end of the cartridge C is preferably recessed as indicated in Fig. 2, so that less material will be exploded in the more confined space at the top of the reflector, thus avoiding excessive pressure at this point.

While this method of firing the cartridges is commonly preferred, an alternative method is indicated in Fig. 18, where the cartridge C' has a cap 127 permanently assembled therewith and adapted to be engaged by a firing-pin 128 in the reflector 129 as the reflector descends. The cap 127 must obviously be protected from the liquid oxygene by coating with some non-porous material.

When starting the rocket, a special initial deto-

nating cartridge may be positioned in the reflector 22 by forcing its upper end into the restricted passage 126 and this cartridge may be fired by such electrical connections as are used in blasting.

This general method of propelling rocket apparatus has many and important advantages. As the cartridges are not closely confined when exploded, extremely high pressures are avoided and it is possible to use detonating charges which act substantially instantaneously and which give off gases at such extremely high speeds that they cannot be safely used in an enclosed or confined space. With the construction herein shown, the pressures against the reflector 22 are not excessive, even with the most powerful explosives, as the forces are reflected rather than resisted. The extremely rapid reflection and ejection of the gases also prevents excessive heating, as the gases are generated at a point substantially removed from the conical surface and are not in contact with the inner surface of the reflector for an appreciable time.

Since the gases strike the surface of the cone at maximum speed and do not require further expansion, the use of an elongated nozzle to utilize the force of expansion is unnecessary. Furthermore, since reflection will take place at any gas velocity and with gas of any density, modification of the nozzle for different velocities and densities is also unnecessary.

Furthermore, I have found by experiment that detonating cartridges produce a greater propulsive force in the described reflecting type of nozzle than was produced in nozzles previously used in rocket apparatus where combustion took place in a confined combustion chamber. I have also found that the propulsive force is greater in a partial vacuum than at atmospheric pressure, which particularly adapts my invention to high altitude research.

For certain purposes, it may at times be desirable to fire all of the remaining cartridges simultaneously. For this purpose a timer 130 (Fig. 1) may be provided which will operate through an electrically fused wire to release a plunger 131 (Fig. 2) which will then enter one of a series of holes 132 in the disc 45 and prevent further rotation thereof, thus stopping the cartridge feed. At the same time, a second electrically fused wire will release a dumping valve 133 by which the entire volume of liquid in the tank 32 will be allowed to flow into the magazine 33 and to soak all of the cartridges remaining therein. The entire charge may then be fired by an explosive head 134 (Fig. 1) also controlled from the timer 130, or it may be fired by impact or in any other desired manner.

In Fig. 21 I have shown a wiring diagram for the load-dumping devices above described. The timing device 130 is connected by wires W' to fusible links F and F', one of which holds the valve 133 in raised or closed position, while the other holds the plunger 131 in raised position. When a circuit is closed by the timer 130 through the wires W', the fusible links F and F' will be melted, whereupon the valve 133 will open and the plunger 131 will move downward to locking position.

The timer 130 is also connected by wires W² to the explosive head or firing device 134 and the circuit is closed by the timer through the wires W² at a predetermined interval after the closing of the circuit through the wires W'. When the circuit is closed through the wires W², the explo-

sive head 134 fires all remaining cartridges which have been soaked by the opening of the valve 133.

Instead of using the large dumping valve 133, I may discharge the remaining liquid in the tank 32 through the regular feed pipe 41 by providing a spring-pressed plunger 140 (Fig. 19) adapted to be electrically released by the timer 130 and to thereafter hold the valve 42 continuously open. The liquid in the tank 32 is usually under some pressure.

If cartridges of a solid detonating mixture are employed, no release of liquid is required and the entire load may be fired at any time by a suitable explosive head as 134.

In the specification and claims the term "rearward" is to be understood as toward the following end of the rocket apparatus when in flight, or toward the lower end of the apparatus as viewed in Figs. 1 and 2.

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 a rocket apparatus, a rearwardly open and unobstructed casing elongated in line of flight, a rearwardly-open gas reflector mounted on said casing and concentric therewith and provided with an internal rearward reflecting surface forming substantially a 90° cone, an elongated explosive cartridge, means mounted in said casing and effective to present said cartridge in the longitudinal axis of said casing and reflector but substantially spaced radially from the side walls thereof and having one end spaced rearward from but adjacent the forward end of said reflector, and means embodied in said apparatus effective to explode said cartridge in said axial position and in said defined relation to said casing and reflector, said conical reflector being thereafter effective to rearwardly reflect the gases produced by the explosion of said cartridge in said reflector along paths substantially parallel to the longitudinal axis of said casing and reflector.

2. The combination in rocket apparatus as set forth in claim 1, in which the gas reflector has an additional parabolic internal reflecting surface at its open rear edge portion, which parabolic surface forms a continuation of the internal conical reflecting surface of said reflector and additionally directs the explosion gases rearward.

3. In a rocket apparatus, a casing elongated in line of flight, a rearwardly-open gas reflector mounted therein and concentric therewith, an annular cartridge-soaking trough mounted in and concentric with said casing and holding a plurality of elongated cartridges parallel to the casing axis, means in said casing to supply and automatically maintain a predetermined amount of liquid oxidizing agent in said trough, devices in said casing effective to remove soaked and explosive cartridges successfully from said trough and to present said cartridges successively in alignment with the axis of said reflector and adjacent to but spaced from the forward end thereof and spaced from the conical side wall thereof, means to actuate said presenting devices, and firing means effective to explode successive soaked cartridges when presented within said reflector, the reflecting inner surface of said reflector being substantially a 90° cone and effective to reflect the explosion gases rearward along paths parallel to the longitudinal axis of said casing and reflector.

4. The combination in a rocket apparatus as set forth in claim 3, in which the gas reflector is mounted for recoil and return movements in said casing, and in which the means for removing and presenting cartridges is engaged and actuated by said reflector during recoil, and in which the exploding means is engaged and actuated by said reflector as its return movement is completed.

5. In a rocket apparatus, a casing elongated in line of flight, an annular soaking trough mounted in said casing and concentric therewith and adapted to hold a plurality of elongated solid porous cartridges parallel to the casing axis, a storage chamber in said casing for a liquid oxidizing agent, means to feed said liquid agent from said chamber to said trough, and means to maintain a fixed level of said liquid in said trough for soaking said cartridges.

6. In a rocket apparatus, a casing elongated in line of flight, a rearwardly open gas reflector mounted in said casing and concentric therewith, an annular soaking trough mounted in said casing and concentric therewith and adapted to hold a plurality of elongated solid porous cartridges parallel to the casing axis, a storage chamber to supply a liquid oxidizing agent to said trough, means to remove successive soaked cartridges from said trough and to successively present said cartridges in axial position within said reflector and adjacent to but spaced from the forward end thereof and spaced from the conical side wall thereof by successive radially inward, upward and additional radially inward movements, and automatic means to explode each cartridge so positioned in said reflector, said reflector having a substantially conical reflecting surface which is effective to reflect the explosion gases rearward along paths parallel to the longitudinal axis of said casing and reflector.

7. Rocket apparatus as set forth in claim 6, in which means is provided to deliver direct to the unused cartridges in said trough and casing all of the remaining liquid oxidizing agent in said storage chamber, and in which additional means is provided to thereafter explode all of the remaining cartridges simultaneously in said trough and casing.

8. In a rocket apparatus, a casing elongated in line of flight, an annular trough in said casing containing a liquid oxidizing agent, a plurality of solid porous elongated cartridges held in said trough parallel to the casing axis and immersed in said liquid agent, a gas reflector rotatably mounted in said casing concentric with the axis thereof and also mounted for reciprocation along said axis, means to explode successive cartridges in said reflector, said reflector being displaced forwardly in said casing by the reaction of each explosion, yielding means in said casing to return said reflector rearward to operative position for the next explosion, means in said casing to intermittently feed said reflector angularly in said casing and relative to said trough, said latter means being actuated by said reflector at each reciprocation thereof, cartridge-feeding devices mounted in said casing and associated with said

trough and successively actuated by said reflector on successive reciprocations thereof, said cartridge-feeding devices being effective to remove successive soaked cartridges from said trough about the entire periphery thereof and to present said cartridges successively in alignment with and adjacent to but spaced from the forward end of said reflector, and magazine means in said casing effective to replace each cartridge removed from said trough by a fresh cartridge which is thereafter removed from said trough by said cartridge-presenting means but only after said intermittent feeding means has advanced said reflector through a substantially complete revolution.

9. The combination in a rocket apparatus as set forth in claim 8, which additionally comprises a plurality of separate cartridge compartments mounted in said casing inwardly adjacent said annular trough, and in which combination said cartridge-presenting means includes means in said casing effective to move each cartridge successively to its associated inner compartments, and means in said casing effective to lift each cartridge successively from its inner compartment to a raised position relative thereto and in which raised position it is engageable by one of said cartridge-feeding devices for movement to axial position in said casing and reflector.

10. In a rocket apparatus, a casing elongated in line of flight, a gas reflector movably mounted in said casing to reciprocate axially and concentrically therein, means actuated by said reflector effective to feed an elongated cartridge radially inward to axial position in said apparatus as said reflector is moved forward by explosion recoil, and means controlled by said reflector and effective to fire said cartridge as said reflector returns to its rearward position, said feeding means including a cartridge carrier, means to hold a cartridge therein, means to move said cartridge transversely of the longitudinal axis of said casing, means to stop and hold said carrier momentarily with its cartridge in axial position in said reflector, means to release the cartridge thus positioned, and means to withdraw said carrier as said reflector moves rearward and before said cartridge is fired.

11. Rocket apparatus as set forth in claim 10, in which the cartridge carrier is mounted on an extensible lazy-tongs linkage which is engaged and elongated toward the casing axis by said reflector in its forward recoil movement.

12. In a rocket apparatus, a casing elongated in line of flight, a gas reflector mounted in and concentric with said casing and having an open rear end, means effective to present an elongated cartridge in alignment with the axis of said casing and reflector and adjacent to but spaced from the forward end of said reflector and substantially spaced from the conical wall thereof, and firing means effective to explode a cartridge thus positioned in said reflector, said firing means including a detonating chamber connected by a restricted passage to the interior of said reflector, and means to produce a detonation therein.

ROBERT H. GODDARD.