United States Patent [19]

Elmore et al.

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[45] **Apr. 16, 1974**

[54] **LIQUID PROPELLANT WEAPON**

[75] Inventors: **Lester C. Elmore,** Portola Valley; **Thomas M. Broxholm,** Palo Alto, both of Calif.

[73] Assignee: **Pulsepower Systems Inc.,** San Carlos, Calif.

[22] Filed: **Sept. 13, 1971**

[21] Appl. No.: **179,759**

[52] **U.S. Cl.** **89/7,** 89/194, 102/38

[51] **Int. Cl.** **F41f 1/04**

[58] **Field of Search** 89/1, 7, 26, 194; 102/38

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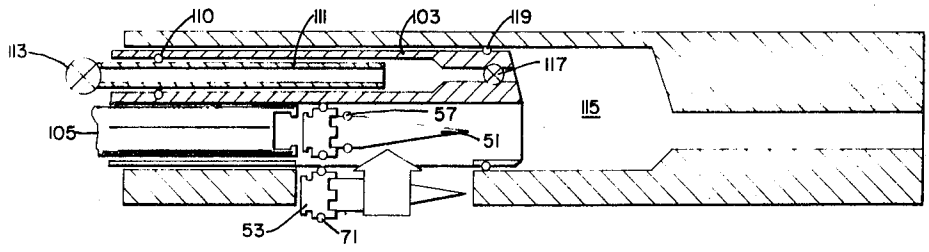
[57] **ABSTRACT**

A small bore liquid propellant weapon fires projectiles transported to the firing chamber in a projectile carrier. The projectile carrier is separated from the projectile just prior to firing the projectile. The projectile carrier can be reconnected with the projectile to extract the projectile from the weapon in the event of a misfire.

The small bore liquid propellant weapon has a reciprocating combustion chamber housing. The reciprocating combustion chamber housing forms a large diameter combustion chamber without ullage and eliminates a lock.

The small bore liquid propellant weapon includes an integral magazine which has its own pump for the liquid propellant. The magazine also has a valve element with high pressure seals that operate only for the life of the magazine and that are discarded with the empty magazine.

19 Claims, 27 Drawing Figures



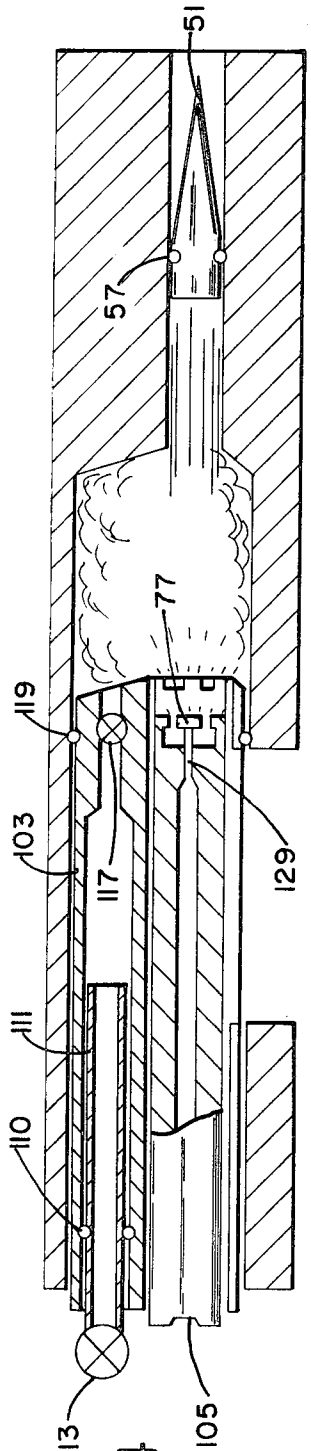


FIG_14

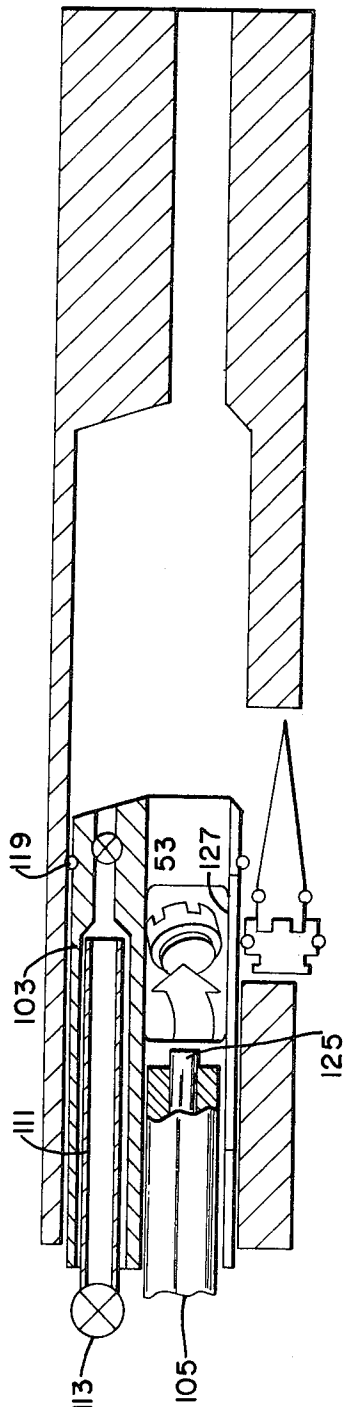


FIG_15

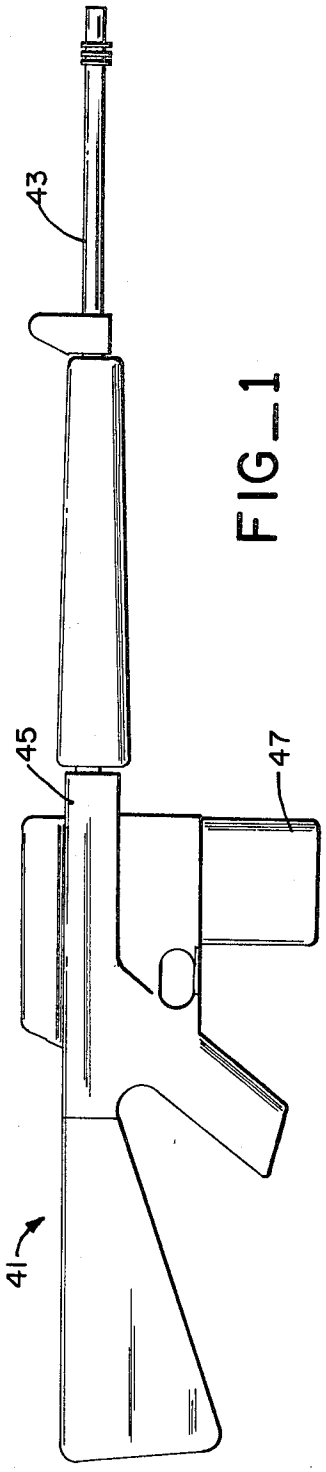


FIG_1

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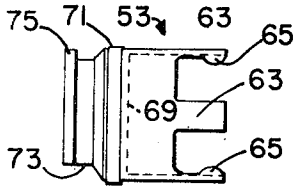


FIG_4

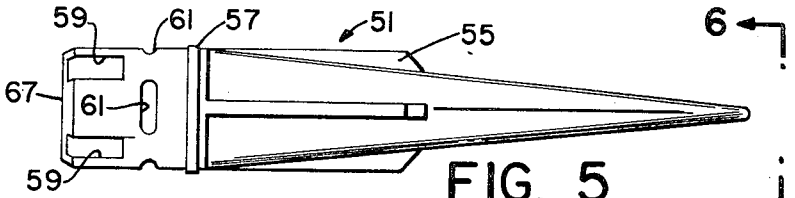


FIG_5

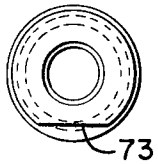


FIG_3

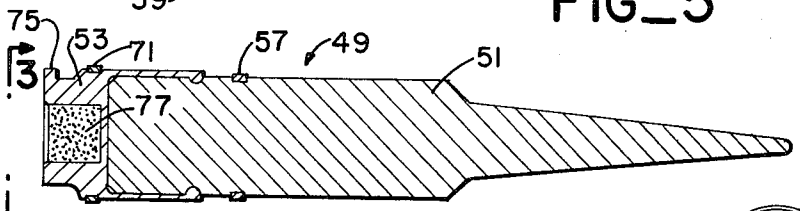


FIG_2

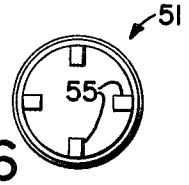


FIG_6

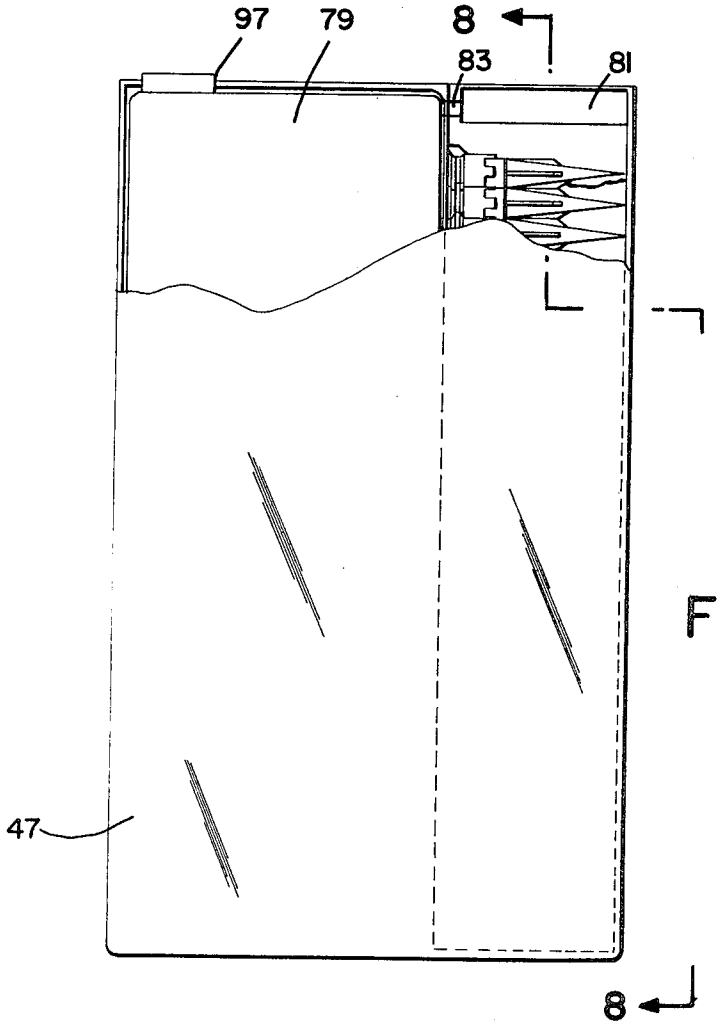


FIG_7

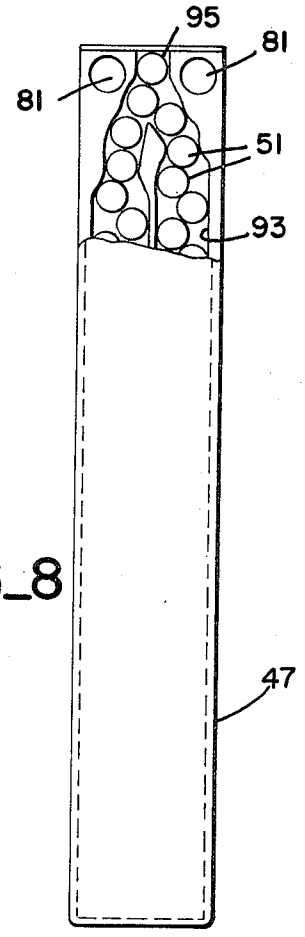


FIG_8

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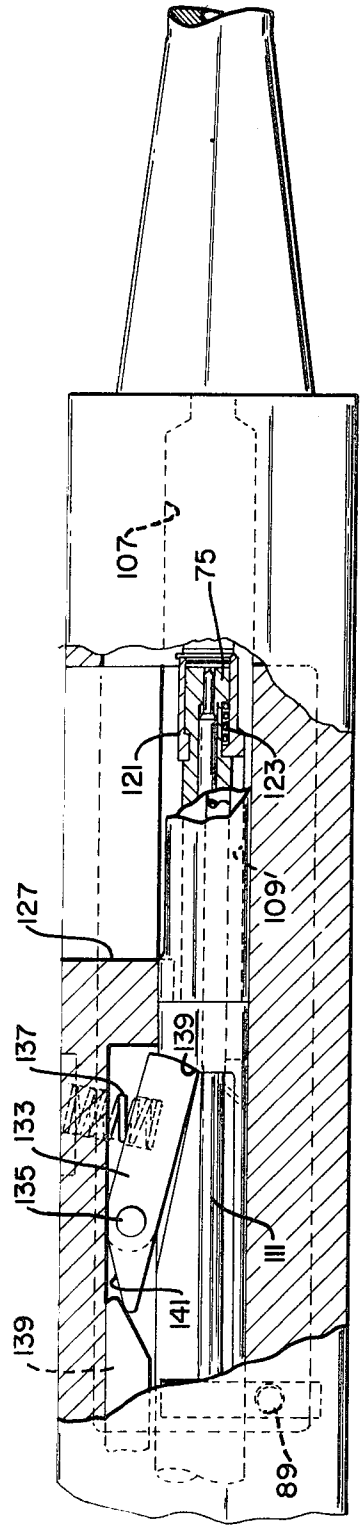


FIG_10

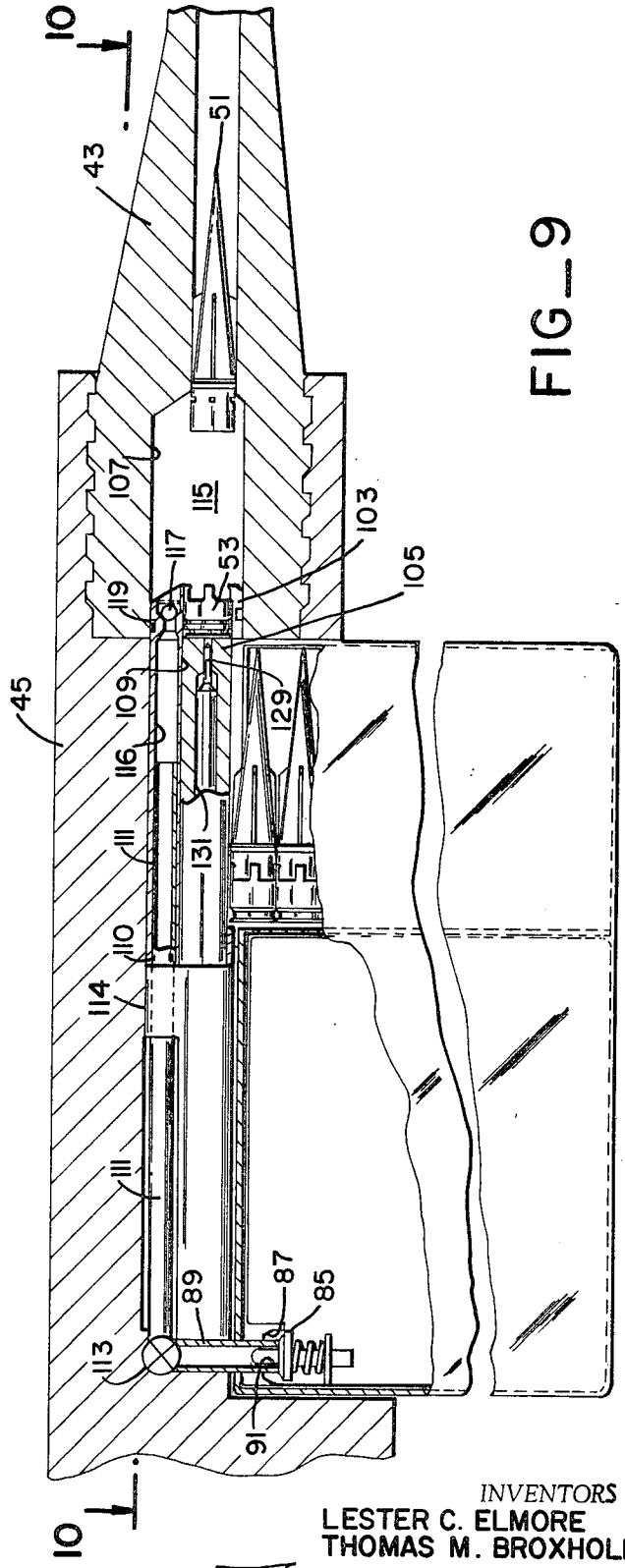


FIG_9

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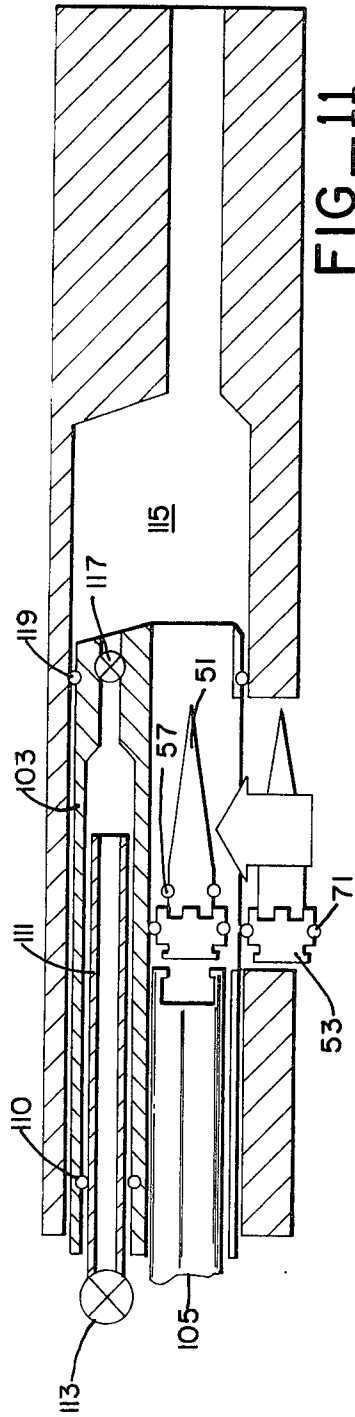


FIG_11

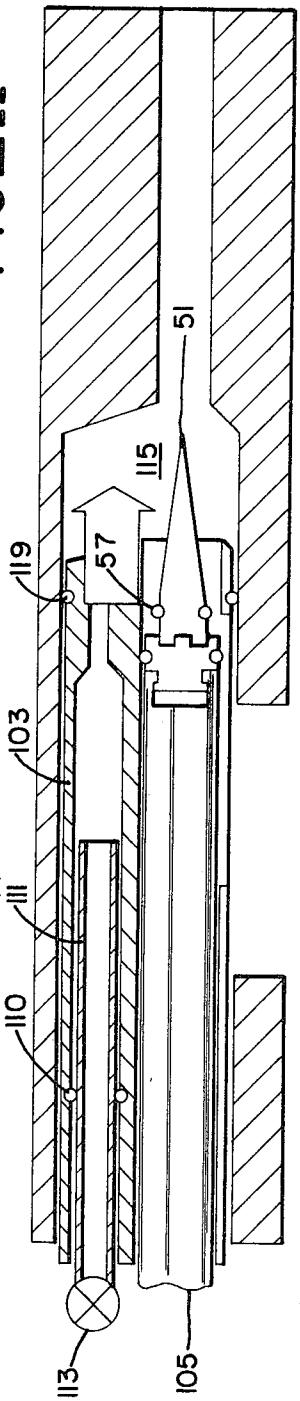


FIG_12

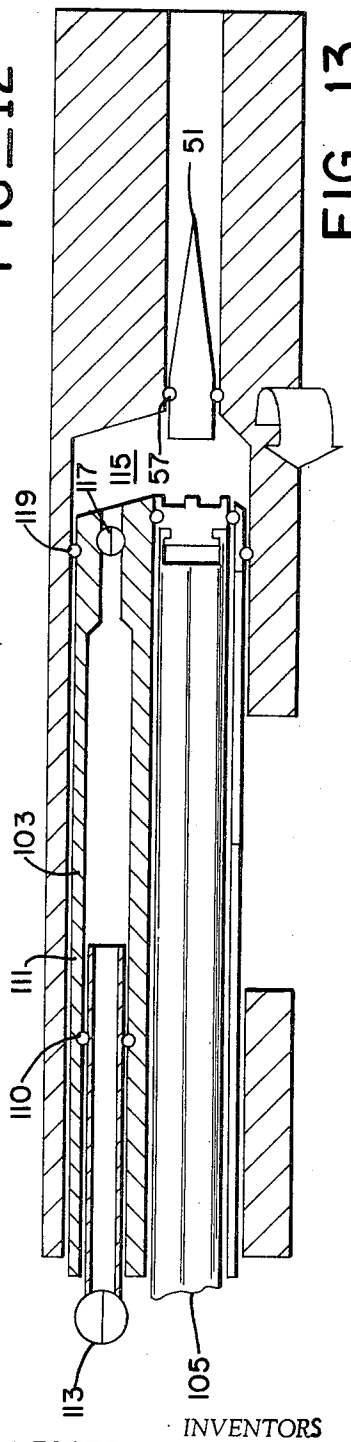


FIG_13

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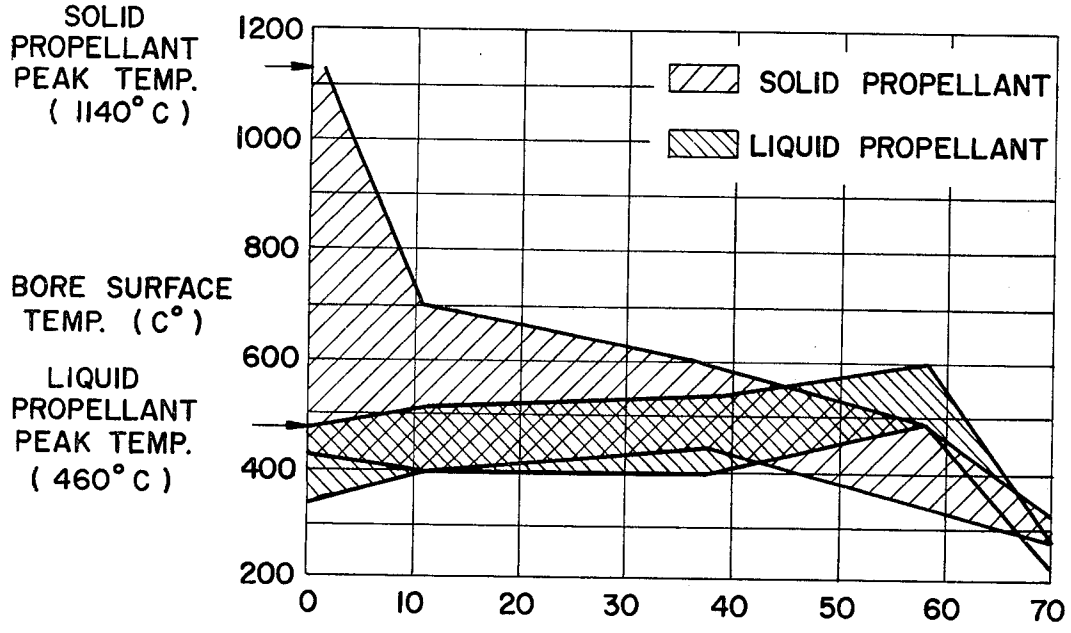


FIG_16

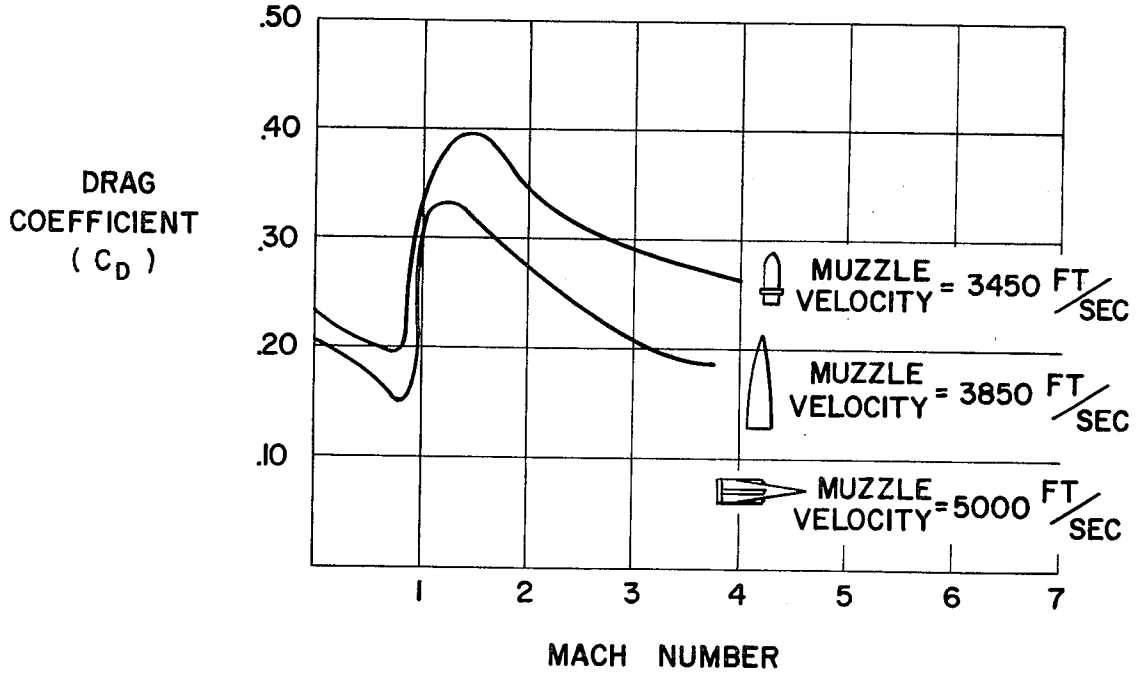


FIG_17

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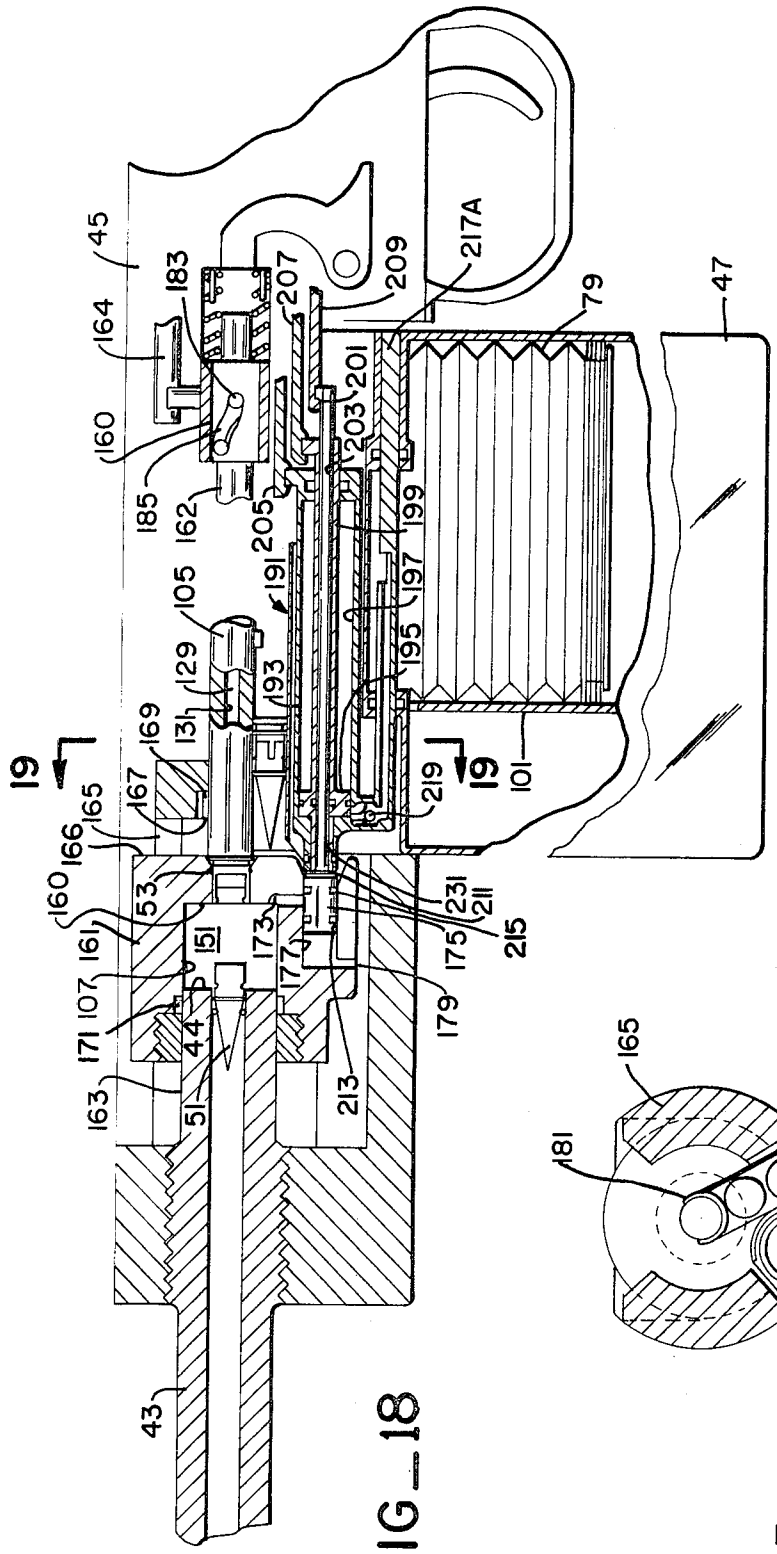


FIG_18

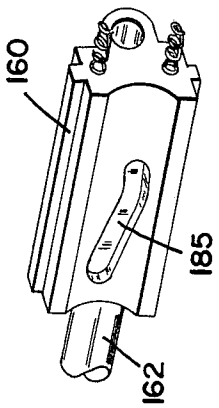


FIG_20

FIG_19

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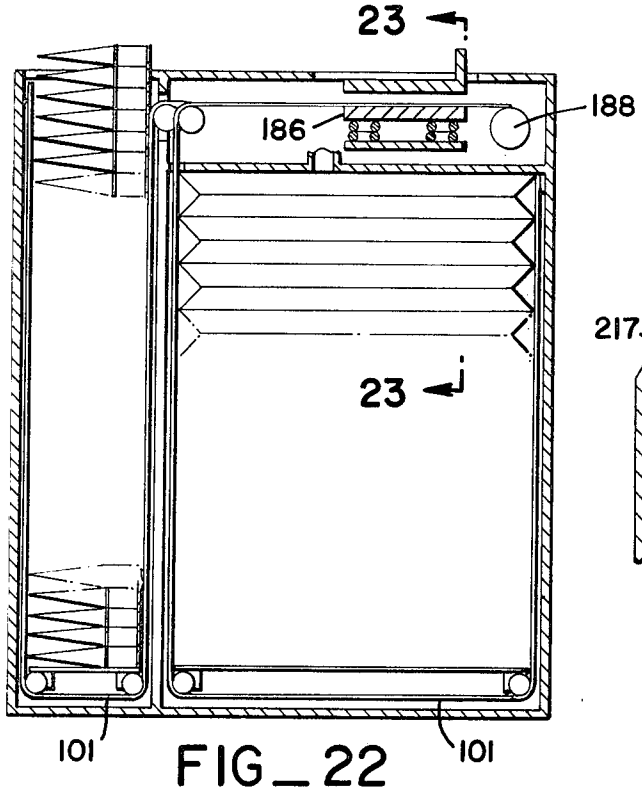


FIG_22

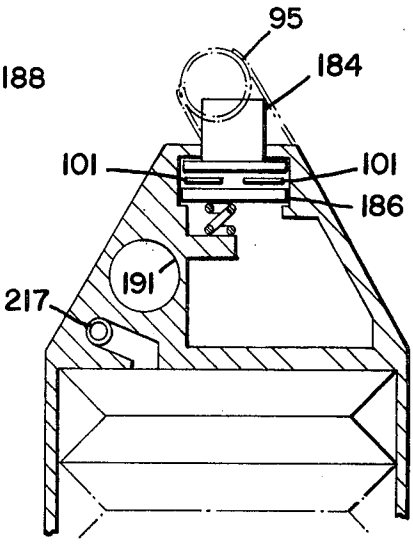


FIG_23

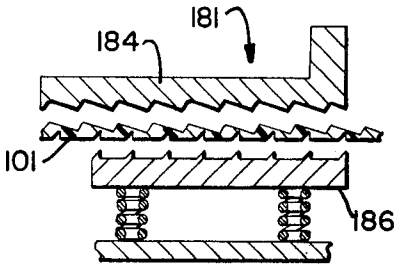


FIG_24

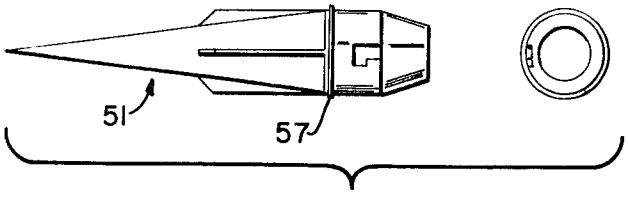


FIG_21A

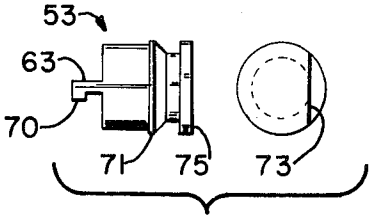


FIG_21B

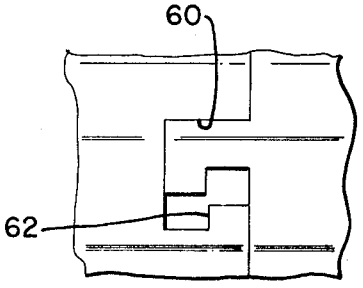


FIG_21D

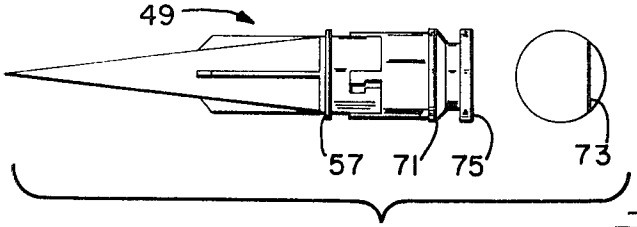


FIG_21C

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LIQUID PROPELLANT WEAPON

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a liquid propellant weapon. The invention relates particularly to a small bore liquid propellant weapon of the kind that can be carried and used by an individual infantryman.

2. Description of the Prior Art

Existing weapons for infantrymen use solid propellant cartridges. The existing weapons carry the solid propellant in cases, and the cases form a substantial part of the overall weight of the cartridge. It is characteristic of the solid propellant that the solid propellant develops a high peak temperature.

The trend in small arms development is towards higher projectile velocity. Higher projectile velocity has a number of advantages. Higher velocity yields increased projectile kinetic energy and penetrating power. Smaller projectiles can be used, and the effective range can be increased.

High velocity, conventional, cased ammunition purchases performance at the expense of increased propellant charge and a larger cartridge case.

The high peak temperatures of solid propellants also can cause problems of barrel erosion. This has limited the velocity obtainable with solid propellants in small bore weapons.

Caseless solid propellant systems have been investigated in an attempt to eliminate the weight of the case. The caseless solid propellant systems have not avoided the problem of high propellant peak temperatures which, heating the barrel, limited the projectile velocity that can be obtained.

Liquid propellant weapons have a characteristic low peak temperature. Substantial investigation has been made of the use of liquid propellants for automatic weapons. However, most of the prior liquid propellant weapon work completed to date has involved equipment of a bore-size larger than caliber 0.60. Prior work with large bore liquid propellant weapons has been directed to a projectile loading concept based on a bore-size chamber in which a caseless projectile is loaded into the breech and is subsequently pumped into the forcing cone by the propellant charge which then completely fills the combustion chamber. While facilitating the projectile loading process, this geometry results in two problems. It becomes extremely difficult to retrieve the projectile in the event of a misfire, since no connection is available to the projectile, nor is there a convenient means of effecting an attachment once the projectile is in place.

An equally important consideration is that of performance limitations. In weapons requiring high muzzle velocity and hence large propellant-to-projectile mass ratios the length to diameter ratio of the combustion chamber becomes excessive for acceptable interior ballistics. The bore-size chamber approach, therefore, has been considered to be limited to velocities of approximately 4,000 feet per second or less.

SUMMARY OF THE INVENTION

The small bore liquid propellant weapon of the present invention has a combustion chamber diameter which is much larger than the bore of the barrel of the weapon.

In a preferred form of the invention the weapon includes a reciprocating combustion chamber housing which allows the formation of a combustion chamber without the introduction of ullage in a ballistic system in which the combustion chamber diameter is larger than the bore diameter of the barrel.

The low length to diameter ratio of the combustion chamber results in a short reciprocating stroke. This minimizes receiver length and improves chamber wall cooling. This also permits the use of a stationary lock for the combustion chamber. It provides a convenient means of thermal isolation of the combustion chamber and a convenient means of handling a projectile in a gun employing chambrage. It permits the velocity level to be readily increased by using a longer chamber and stroke. It also permits the length of propellant passages in a receiver mechanism to be limited, and this in turn simplifies the mechanism, eliminates voids and eliminates propellant filled passages which could transmit flame from the combustion chamber to the propellant supply in the magazine.

In the present invention the projectile is carried in a projectile carrier which is separated from the projectile prior to firing. The projectile is a low drag conical projectile. It has the shape of a reentry body with a narrow angle cone and is aerodynamically stabilized.

The carrier contains a percussion igniter which allows the use of existing ignition techniques applicable to any of the current liquid propellant systems.

The carrier can be reengaged with the projectile to remove the projectile in the event of misfire.

The projectile carrier is also a key element in transporting the projectile through the larger than bore diameter chamber (chambrage) which is necessary in a high performance gun.

The weapon of the present invention includes a magazine which has a pumping mechanism integral with the magazine. The pumping mechanism is operated by the action of the reciprocating bolt of the weapon. A propellant supply valve and high pressure seals on the valve are an integral part of the magazine. The incorporation of the high pressure seals as an integral part of the magazine, and the manner in which the magazine and the high pressure valve are associated with the rest of the weapon have several advantages. The high pressure valve element and seals have to operate only for the life of the magazine. The valve element and seals are discarded with the empty magazine. A new high pressure inlet valve element and new high pressure seals are provided each time the magazine is replaced.

Other and further objects of the present invention will be apparent from the following description and claims and are illustrated in the accompanying drawings which, by way of illustration, show preferred embodiments of the present invention and the principles thereof and what are now considered to be the best modes contemplated for applying these principles. Other embodiments of the invention embodying the same or equivalent principles may be used and structural changes may be made as desired by those skilled in the art without departing from the present invention and the purview of the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevation view of a small bore liquid propellant weapon constructed in accordance with one embodiment of the present invention;

FIG. 2 is a side elevation view in cross section of a projectile-carrier assembly constructed in accordance with one embodiment of the present invention;

FIG. 3 is an end elevation view taken along the line and in the direction indicated by the arrows 3—3 in FIG. 2;

FIG. 4 is a side elevation view of the carrier alone;

FIG. 5 is a side elevation view of the projectile alone;

FIG. 6 is an end elevation view taken along the line and in the direction indicated by the arrows 6—6 in FIG. 5;

FIG. 7 is a side elevation view (partly broken away to show details of construction) of a magazine constructed in accordance with one embodiment of the present invention;

FIG. 8 is an end elevation view taken along the line and in the direction indicated by the arrows 8—8 in FIG. 7;

FIG. 9 is a fragmentary, enlarged, side elevation, cross-sectional view showing the magazine loaded in the weapon;

FIG. 10 is a top plan view taken generally along the line and in the direction indicated by the arrows 10—10 in FIG. 9;

FIGS. 11–15 are schematic side elevation views of the structure shown in FIG. 9 showing the position assumed by the different elements of the structure during a cycle of automatic firing operation;

FIG. 16 is a graph showing the comparison of temperatures in a barrel for solid propellants and for liquid propellants;

FIG. 17 is a graph showing the drag coefficient for different types of projectiles;

FIG. 18 is a fragmentary side elevation view in cross-section, like FIG. 9, of a weapon constructed in accordance with another embodiment of the present invention. The embodiment shown in FIG. 18 incorporates a reciprocating combustion chamber housing;

FIG. 19 is an end elevation view taken generally along the line and in the direction indicated by the arrows 19—19 in FIG. 18;

FIG. 20 is a plan view showing the cam paths for actuating the bolt of the embodiment shown in FIG. 18;

FIGS. 21 A through D are side elevation views of a carrier incorporating a positive misfire extraction construction;

FIG. 22 is a side elevation of a magazine constructed in accordance with another embodiment of the present invention;

FIG. 23 is a fragmentary sectional view taken generally along the line and in the direction indicated by the arrows 23—23 in FIG. 22; and

FIG. 24 is a detail view of a strap transfer mechanism.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A small bore liquid propellant weapon constructed in accordance with one embodiment of the present invention is indicated generally by the reference numeral 41 in FIG. 1.

The weapon 41 is illustrated as a shoulder weapon. The present invention could also be embodied in other types of weapons, such as hand weapons or vehicle mounted weapons.

The principal components of the weapon 41 are a barrel 43, a receiver assembly 45 and a magazine 47.

The receiver assembly will be described with reference to FIGS. 9 and 10 for one embodiment of the present invention and with reference to FIGS. 18 and 19 with reference to another embodiment of the present invention.

The magazine 47 will be described below with reference to FIGS. 7, 8, 9, 18, 22 and 23.

The magazine 47 supplies liquid propellant and projectiles to the receiver assembly 45 of weapon 41. Each of the projectiles is transported through the magazine and receiver assembly and into the firing chamber by a carrier. The projectile is separated from the carrier prior to firing.

A projectile-carrier assembly constructed in accordance with one embodiment of the present invention is illustrated generally by the reference numeral 49 in FIG. 2. The projectile-carrier assembly 49 includes a projectile 51 and a carrier 53.

The projectile 51 may have a reentry body configuration (as illustrated) with a narrow angle cone. The reentry body shape is aerodynamically stabilized and has a low drag coefficient as shown by the chart of FIG. 17. The projectile can also be a conventional spin stabilized configuration.

The projectile 51 includes in bore stabilizing fins 55, a projectile seal 57, propellant flow grooves 59 and recesses or grooves 61 for attachment to the carrier 53.

The seal 57 also serves to retain the projectile in the barrel after the projectile is loaded.

The carrier 53 has a relatively short axial length so as to contribute little additional length to the overall projectile-carrier assembly. The carrier has a number of forwardly extending fingers or clips 63, and each finger or clip 63 has a radially inwardly extending dimple or projection 65 which seats in a groove 61 of the projectile.

When the carrier projectile assembly is placed in the bore, liquid propellant is pumped through the propellant flow groove 59 and between the back face 67 of the projectile and the inner face 69 of the carrier to pump or force the carrier 53 backwards to the rear end of the firing chamber of the receiver assembly in a manner which will be described in detail below with reference to FIGS. 11–15. The resilient fingers 63 flex to permit the dimple 65 to release from the groove 61 during this separation operation.

In the event of a misfire the carrier 53 can be moved forward and can be reconnected with the projectile 51 to extract the projectile from the firing chamber in a manner also to be described in greater detail below.

The carrier 53 includes a carrier seal 71.

The carrier also includes an alignment flat 73, best shown in FIG. 3. The alignment flat 73 coacts with a corresponding flat on the bolt to align the projectile-carrier assembly in a manner to be described below.

The flat 73 maintains orientation of the carrier relative to the projectile during the cycle, thus insuring that the dimples will properly reengage the projectile in the event it must be removed from the bore in the event of malfunction.

The carrier 53 also includes an extraction lip 75. This extraction lip 75 is engaged by a part on the bolt after the projectile has been fired.

The magazine 47 (as shown in FIGS. 7, 8, 9, 22 and 23) carries both the propellant and the projectile-carrier assemblies. The propellant supply is carried in a flexible tank or reservoir 79 within the magazine

housing. As best shown in FIGS. 22 and 23 the flexible tank 79 may have accordion type pleating and can be operated by a tape drive mechanism 181 actuated by the bolt to lift the bottom of the tank 79 on each cycle of operation to pump propellant into the weapon.

The magazine shown in FIG. 7 includes expansion tanks 81 connected to the main tank 79 by conduits 83.

As best shown in FIG. 9 the propellant supply part of the magazine includes a spring loaded valve element 85 which seats in a valve seat 87 when the magazine is not associated with the weapon. When the magazine is connected to the weapon, downwardly extending tube 89, as shown in FIG. 9, pushes the valve element 85 downwardly to establish fluid communication through a slot 91 in the sidewall of the tube 89.

The projectile-carrier assemblies are fed upwardly through a pair of channels 93 and into a common channel 95 and then into the receiver assembly of the weapon by the same bolt actuated elevator mechanism used to lift the bottom wall of the propellant supply tank or reservoir 79.

A specific description of the lift mechanism for the magazine is set forth below with reference to FIGS. 22–24.

A strippable top 97 retains the projectiles in place until the magazine is loaded into the weapon.

A number of liquid propellants have been found satisfactory for the weapon of the present invention. They include but are not limited to mono propellants such as hydrazine nitrate composed of 35% $N_2H_5NO_3$, 5% H_2O and 60% N_2H_4; Monomethyl Hydrazine Nitrate 90%; Ethyl Propyl Nitrate 60/40; Otto Fuel II.

A metal partition in the magazine serves to positively isolate the primers in the projectile-carrier assembly from the propellant in the tank 79 to preclude inadvertent ignition. A suitable strap transfer mechanism can be associated with the elevator strap 101, as shown in FIG. 24.

The receiver assembly 45, as shown in FIG. 9, has a two-part bolt assembly. The bolt assembly includes an outer bolt 103 and an inner bolt 105.

The outer bolt is reciprocal within a bore 107 in the receiver assembly 45 and barrel 43.

The inner bolt 105 is reciprocable within a bore 109 in the outer bolt.

The tube 89 connecting the propellant supply in the magazine also connects a tube or conduit 111 in the receiver assembly through a propellant control valve 113. The forward end of the tube 111 slides within a bore 114 in the outer bolt in trombone fashion during the reciprocation of the outer bolt 103.

A seal 110 seals between the tube 111 and the bore 113.

The forward end of the conduit 116 connects to the combustion chamber 115 through a spring biased one way ball check valve 117 in the forward face of the outer bolt 103.

A seal 119 is carried at the forward end of the outer bolt to seal against the wall 107 of the combustion chamber 115.

The forward end of the inner bolt 105 includes extractor clip 121 which is resiliently biased by a spring 123. The forward ends of the resilient arms of the clip 121 clip over the extraction lip 75 of the carrier to remove the carrier from the bore 109 after firing.

An off center ejector pin 125 in the inner bolt (See FIG. 15) kicks the carrier out through an ejection slot 127 in the outer bolt and in the receiver assembly 45.

A firing pin 129 is reciprocable within a bore 131 in the inner bolt 105 to ignite the propellant igniter 77 in the carrier.

A bolt lock 133, see FIG. 10, is pivoted about a pivot 135 and is spring biased towards the position illustrated in FIG. 10 by a spring 137 to place the forward face of the bolt lock in locking engagement with the rear face 139 of both the outer bolt 103 and the inner bolt 105. A cam 139 moves forward and engages a corresponding cam surface 141 on the bolt lock 133 to pivot the bolt lock against the force of the spring 137 to release the bolt at the end of the firing cycle.

The operation of the weapon thus far described is illustrated in FIGS. 11–16 which illustrate respectively projectile transfer, projectile ramming, propellant loading, combustion, and the carrier ejection.

The automatic firing cycle is initiated with the bolt in the open position after the firing of a burst. This eliminates cook-off of a round in the hot breech. Propellant isolation is effected by supplying the propellant through the bolt. This allows insertion of a thermal barrier between the barrel and receiver group, effectively isolating the hot barrel from those components in direct contact with liquid propellant.

There is little likelihood of dynamic cook-off of propellant during loading. Static cook-off, however, can be a problem, as it is with caseless solid propellant ammunition.

It is therefore an important feature of the present invention that the propellant supply is isolated from those hot surfaces which might effect ignition of a chambered round or ignition in the propellant supply.

When released by the trigger operated sear, the bolt pcks up a carrier and projectile from the clip and inserts the assembly into the bolt bore. The bolt-operated elevator mechanism of the magazine, described above, effects this action by lifting the entire string of projectile-carrier assembly described above.

The flat 73 on the carrier extractor ram aligns the carrier.

The bolt is then driven forward, as illustrated in FIG. 12, by the operating mechanism until the projectile 51 engages the bore opening of the weapon at the forward end of the combustion chamber 115.

The propellant valve 113 is then opened, as illustrated in FIG. 13. This allows propellant supply pressure to 1) seat the projectile, 2) separate the projectile carrier from the projectile within the bolt, and 3) fill the combustion chamber 115 with propellant as the bolt is moved rearward, as illustrated in FIG. 13, to its firing position.

During this phase of operation the propellant flows past the one-way ball check valve 117 and enters the carrier through the opening between the fingers or clips 63 in the carrier wall. The propellant flows through the propellant flow grooves 59 in the projectile 51 and acts on the rear face 67 of the projectile 51 and the forward inner face 69 of the carrier.

When the firing chamber 115 is filled, the bolt is locked in its rear position by the lock 133 (See FIG. 10).

The firing pin 129 is released, and the firing pin strikes the percussion primer 77, igniting the liquid propellant charge in the combustion chamber 115.

After projectile exit, the bolt is opened, the spent projectile carrier is ejected as illustrated in FIG. 15,

and a subsequent cycle is initiated as long as the trigger is depressed.

The weapon may also be operated in a semi-automatic mode if a burst has not been fired recently. In the semi-automatic mode the man firing the gun hand operates an operating handle to fill the firing chamber **115** with propellant and to position the parts in their relative positions as assumed at the end of propellant loading as illustrated in FIG. **13.** In this case the weapon is in effect cocked and ready to fire when the trigger is pulled and the firing pin is released to engage the igniter **77** as illustrated in FIG. **14.** The weapon can continue to operate in the semi-automatic mode as long as the chamber **115** does not become hot enough to allow static cook-off.

A thermostatic element can be included in the weapon to override semi-automatic operation when the chamber housing is too hot to allow semi-automatic operation from a filled chamber.

As illustrated in FIG. **17** the drag coefficient for the reentry body projectile is quite low, especially in comparison to projectiles having configurations which are presently being used. The small bore liquid propellant gun of the present invention permits the use of this reentry body configuration by providing the requisite high velocity for aerodynamic stabilization. The weapon of the present invention can produce high velocity (as a practical matter) because the liquid propellant combustion does not heat the barrel as much as solid propellant combustion. The cooler burning characteristics of the liquid propellant are graphically illustrated in FIG. **16.** This figure shows the envelope of peak bore surface temperatures during eight round bursts of liquid and solid propellant ammunition.

A weapon constructed in accordance with another embodiment of the invention is illustrated in FIGS. **18, 19** and **20.**

The weapon shown in FIGS. **18** and **19** embodies two important features.

A reciprocating combustion chamber housing slides over the rear end of the barrel and replaces the conventional bolt mechanism.

The magazine is a completely self-contained magazine which incorporates a propellant pump, a chamber high pressure inlet valve and a clip of projectile-carrier assemblies.

When the reciprocable combustion chamber housing of the embodiment of the weapon shown in FIG. **18** is fully forward, the combustion chamber is completely eliminated. As the housing moves to the rear, the combustion cavity is formed in a manner which eliminates ullage.

This embodiment of the present invention achieves a low length to diameter ratio for the combustion chamber. This minimizes receiver length and improves chamber wall cooling due to the liquid annulus remaining at the time of initiation.

This reciprocating housing construction permits the use of a static lock for the combustion chamber.

Combustion loads are not carried through a receiver but are carried through the static members linking the barrel to the chamber.

It provides convenient means of thermal isolation for the chamber.

It permits ready increase of velocity level by using a longer chamber and stroke.

Propellant passages in the receiver mechanism are eliminated which simplifies the mechanism, eliminates voids and eliminates propellant filled passages which could transmit flame from the combustion chamber to the propellant supply in the magazine.

As illustrated in FIG. **18** a combustion chamber housing **161** slides back and forth on the outer surface **163** of the end of the barrel **43.**

The housing **161** is shown in its rearward most position in FIG. **18** ready for firing. The combustion chamber housing **161** and the bolt **105** are held in this position by a static or stationary lock **165.** The lock **165** abuts the back face of the housing **161.** The lock **165** includes an inner recess **167** hwich engages a radially projecting tang **169** of the bolt. The tank **169** is rotated into locking engagement with the recessed surface **167** of the lock.

A seal **171** at the forward end of the housing **161** seals between the housing **161** and the barrel surface **163.**

Liquid propellant is admitted to the combustion chamber **151** through a port **173** in the housing **161.**

A valve element **175** controls the admission of liquid propellant through the port **173.** The valve element **175** is reciprocable within a bore **177** in the housing **161,** and a vent **179** vents the forward end of the bore **177.**

As described below, a strap transfer mechanism **181** is operated by movement of the bolt to lift a toothed strap **101** to elevate the bottom wall of the propellant tank **79** and the bottom wall of the clip for the projectiles on each cycle of operation.

FIGS. **22** and **23** illustrate schematically operation of the strap transfer mechanism **181.** Two straps **101** are provided, one to raise the projectiles and the other to compress the propellant supply bellows.

The strap transfer drive tang **184** engages a slot in the bolt which causes reciprocation of drive tang **184.** During rearward motion of the tang its teeth engage corresponding teeth on plastic strap **101** causing it to be transported to the rear and at the same time rotating take up reel **188.** When the bolt moves forward, holding clutch **186** prevents relaxation of the tension on strap **101.** Excess tension in the strap is prevented by slipping action between the drive teeth of tang **184** and strap **101** which is controlled by the spring load on holding clutch **186.**

FIG. **19** illustrates the manner in which the projectile-carrier assemblies are fed into position in the front of the bolt.

A pair of resilient clips at the upper end of the passage **95** holds the uppermost projectile in position until the forward movement of the bolt pushes the projectile carrier into the combustion chamber.

A tang or cam follower **183** on the bolt engages a groove or cam path **185** to control rotation of the bolt during reciprocating movement as illustrated in FIG. **20.**

As noted above, the flow of propellant to the combustion chamber **51** is under the control of a valve element **175.** This valve element **175** is a part of a pumping assembly which is indicated generally by the reference numeral **191** and which is an integral part of the magazine **47.**

The pumping assembly **191** includes three operating elements. These elements are a reciprocable outer housing **193,** a piston **195** and the valve element **175.**

The piston **195** slides within a bore **197** within the outer housing **193**, and is connected to a piston rod **199** which extends outwardly through a sealed opening in the rearward end of the outer housing **193**.

The valve element **175** is connected to a rod **201** which extends through a seal in the piston **195** and which is reciprocable within a bore **203** in the rod **199**.

The outer housing **193**, the rod **199** and the rod **201** each have an upwardly extending lip which is releasably engaged by an operating element **205**, **207** and **209** respectively of the weapon.

The rear face of the valve element **175** has a seal element **211** which engages a forward annular face of the outer housing **193** in sealing relationship in the position illustrated in FIG. **18**.

The valve element **175** also includes sealing members **213** and **215**. These sealing elements are high pressure seals which prevent any flow out the combustion chamber **151** during combustion.

Propellant is drawn into the chamber formed in the bore **197** in front of the piston **195**, during one phase of operation of the weapon, through a conduit **217** in the outer housing **193** and past a spring biased one-way ball check valve **219**. The conduit **217** has an extension **217A** which compensates for reciprocation of the conduit **217** within the reservoir **79** to prevent an unequal displacement of volume during reciprocation.

As in the embodiment of the invention described with reference to FIGS. **9–15**, the embodiment illustrated in FIGS. **18** and **19** can operate in two modes — the automatic mode for firing bursts and semi-automatic mode.

The automatic mode is started with the bolt **105** fully retracted behind the projectile assembly. The reciprocating combustion chamber housing **161** is fully rearward with the rear face **166** in abutment with the lock **165**.

At this point the strap **101** has operated to lift the bottom of the magazine to position a projectile-carrier assembly in front of the bolt.

The bolt **105** is then moved forward. This transfers the projectile-carrier assembly forward until the projectile **51** is seated in the barrel and the elastomer seal **57** engages the inside of the barrel to form a liquid seal.

Locking and unlocking of the bolt is controlled by the action of the cam path **185** on the bolt cam follower **183**. Forward and backward movement of the cam slide **160** is controlled by the gas piston push rod **162**. This camming action rotates the bolt prior to forward or backward movement of the bolt assembly. A manual override **164** is provided to permit hand operation of the bolt in event of misfire.

In a typical firing cycle the gas piston push rod **162** is driven to the rear by combustion gasses as the projectile passes by a gas port near the muzzle. Rearward motion of the push rod **162** and cam slide **160** rotate the bolt cam follower **183** counterclockwise (viewed from the rear) to disengage the bolt tang **169** from the bolt lock inner recess **167** allowing the bolt to move to the rear, extracting and ejecting the spent projectile carrier. At its rearmost position the bolt picks up a new projectile and carrier assembly and during forward motion loads this assembly into the combustion chamber housing. Continued forward motion of the cam slide **160** rotates the bolt clockwise and carries the combustion chamber housing **161** forward until barrel surface **44** is in abutment with housing surface **160** at which time the pumping cycle is initiated as described above.

FIGS. **21A–D** show another embodiment of a projectile-carrier assembly incorporating a coacting tang and slot construction for positive extraction in the event of misfire. The propellant-flow ports and grooves are omitted in FIGS. **21A–D** for clarity of illustration but are the same as in the embodiment shown in FIGS. **2–5**.

As best shown in FIG. **21B**, the carrier has a tang **70** the end of a finger **63**.

As best shown in FIG. **21D** the projectile has a slot **60** with a recess **62**.

In normal operation the tang **70** does not engage the recess **62**. The spring action of the fingers **63** hold the projectile in place during loading.

If there is a misfire, the normal counterclockwise rotation of the bolt causes the tang **70** to be engaged in the recess **62** when the carrier is reconnected to the unfired projectile.

The tang **70** is never engaged in the recess **62** except in the event of a misfire. The normal loading and locking movement of the bolt is clockwise.

As the bolt is moved forward, the outer housing **193** of the pumping assembly **191** is also moved forward with the valve element **175**. This permits propellant to flow through the passage **217** and pass the check valve **219** into a chamber which is formed between the front face of the piston **195** and the rear inner face of the forward part of the valve of the outer housing **193**.

The forward movement of the outer housing **193** and the valve element **175** is then discontinued while the forward movement of the valve element **175** is continued. The valve element **175** jogs forward enough to uncover the port **173**. Propellant can then flow from the chamber in front of the piston **195** through the bore **231** in the center part of the forward end of the outer housing **193** and through the port **173** and into the combustion chamber **151**.

The outer housing **193** is then moved to the rear by the actuating mechanism **205** while the piston **195** is held stationary. This pumps the propellant into the combustion chamber **151**. This in turn moves the reciprocating combustion chamber housing **161** to the rear and separates the carrier **53** from the projectile **51**.

When the rearward movement of the pump outer housing **193** and the combustion chamber housing **161** has been completed, and the housing **161** is in abutment with the stationary lock **165**, actuating element **209** then pulls valve element **175** rearward to the position illustrated in FIG. **18** in which the high pressure seals **213** and **215** seal off any fluid flow through the port **173**.

The bolt **105** is moved to the rear with the rearward movement of the housing **161**.

At this point the weapon is ready for firing, and firing is accomplished by the hammer striking the firing pin **129** to force the forward end of the firing pin into engagement with the back face of the carrier **53** to ignite the igniter **77**.

A conventional gas operated linkage connected to the bolt gives the bolt a kick to the rear when the projectile passes the gas operator.

An off center ejector pin in the bolt, like the pin **125** shown in FIG. **15** tumbles the spent carrier out through an ejection slot.

In the event of a misfire the valve element **175** is moved forward to uncover the port **173**, and a manually actuated misfire mechanism pushes the housing

161 forward to pump out the propellant from the combustion chamber 151.

The bolt 105 is rotated with respect to the carrier 58 to engage the extraction clips of the bolt in the slot of the carrier to produce a positive grip between the bolt and the carrier. The bolt is then pulled back to extract the carrier and the projectile 51, and the entire reengaged carrier and projectile assembly is ejected through the ejection slot at the end of rearward movement of the bolt.

In the semi-automatic mode the parts are manually actuated for the first shot to the relative positions illustrated in FIG. 18 so that the weapon is ready to fire when the trigger is pulled.

As described above, with reference to the first embodiment of this invention, a thermostatic element can be provided to override the semi-automatic operating mechanism when the chamber housing is too hot to allow semi-automatic operation from a filled chamber.

To remove the magazine 47 from the weapon illustrated in FIG. 18, a clip release is actuated to move the outer housing 193, the piston 195 and the valve element 175 to the rear and to release the magazine housing from the receiver 45.

It is an important feature of the embodiment of the present invention shown in FIG. 18 that propellant passages in the receiver mechanism are eliminated. The only free volume is the connection from the combustion chamber 151 to the bore 177 through the relatively small port 173.

The high pressure seals 213 and 215 are replaced each time a new magazine is used.

The flat seal 211 provides positive propellant isolation, and there is always an atmospheric vent after the high pressure seal 215 and before getting to the propellant in the reservoir 79.

While we have illustrated and described the preferred embodiments of our invention, it is to be understood that these are capable of variation and modification, and we therefore do not wish to be limited to the precise details set forth, but desire to avail ourselves of such changes and alterations as fall within the purview of the following claims.

We claim:

1. A method of loading liquid propellant into a firing chamber of a liquid propellant gun to avoid ullage problems comprising placing the forward face of a firing chamber in line contact with the rear face of the firing chamber, loading a projectile carrier assembly in firing position in the bore of the gun while the front and rear faces of the firing chamber are maintained in line contact, then pumping liquid propellant into the firing chamber to displace the rear face of the firing chamber axially with respect to the front face of the firing chamber, separating the carrier from the projectile as liquid propellant is pumped into the firing chamber, retaining the projectile in the forward face of the firing chamber and retaining the carrier in the rear face of the firing chamber as these two faces are axially separated, and then igniting the liquid propellant in the firing chamber to fire the projectile out the barrel of the gun.

2. A method as defined in claim 1 including pumping the liquid propellant out of the firing chamber in the event of a misfire, moving the rear face of the combustion chamber into line contact with the front face of the combustion chamber as the liquid propellant is pumped out of the firing chamber, reconnecting the carrier to the projectile as the faces of the combustion chamber are reengaged in line contact, and then extracting the projectile-carrier assembly from the gun.

3. A method as defined in claim 1 including locating the mechanism for pumping the liquid propellant into the firing chamber in structure associated with the rear face of the firing chamber and maintaining the mechanism for pumping the liquid propellant spaced from the firing chamber housing and from the barrel of the gun after the firing chamber housing and the barrel have been heated to high temperatures by the firing of a burst to thereby provide thermal isolation of the propellant from the hot barrel and the housing.

4. A method as defined in claim 1 wherein the rear face of the combustion chamber is part of a reciprocating combustion chamber housing.

5. A method as defined in claim 1 wherein the rear face of the combustion chamber is a part of the bolt assembly.

6. A liquid propellant gun of the kind in which a projectile is loaded in the gun and liquid propellant is pumped into the combustion chamber behind the projectile and is ignited to fire the projectile from the gun,

said gun comprising a combustion chamber having a front face and a rear face,

said front face having an opening for the projectile,

said rear face being shaped complementary to the front face to engage the front face in line contact across the full surface of the front face except for the area of said opening,

moving means for moving one face relative to the other face into said line contact with the other face and for moving the one face away from the other face and into firing position,

projectile loading means coordinated with said moving means for loading a projectile in the opening in the front face while the rear face is engaged in said line contact with the front face across said full surface of the front face,

pumping means for pumping a liquid propellant into the combustion chamber,

and propellant control valve means effective to admit the pumped liquid propellant into the combustion chamber at the start of movement of the one face away from the other face and to continue to admit said liquid propellant continuously and in coordination with the movement of the other face by said moving means to said firing position to thereby fill the entire chamber volume with liquid propellant simultaneously with the formation of the chamber and prevent ullage in the combustion chamber.

7. A gun as defined in claim 6 wherein the projectile has an elastomer seal and projectile holder extending circumferentially around the projectile and engageable in fluid sealing and projectile retaining relationship with the opening in the front face of the combustion chamber.

8. A gun as defined in claim 6 wherein the diameter of the combustion chamber is considerably larger than the diameter of the projectile to provide large propellant-to-projectile mass ratios for high muzzle velocities and small combustion chamber length-to-diameter ratios for acceptable interior ballistics.

9. A gun as defined in claim 6 including a magazine containing a clip of projectile-carrier assemblies and a tank of liquid propellant, and wherein the pumping

means include a movable piston and high pressure seals in the magazine structure.

10. A liquid propellant gun of the kind in which a projectile is loaded in the gun and liquid propellant is pumped into the combustion chamber behind the projectile and is ignited to fire the projectile from the gun,
said gun comprising, a combustion chamber having a forward face and a rear face,
said front face having an opening for the projectile,
moving means for moving the rear face forward into line contact with the front face and for moving the rear face backward away from the front face and into firing position,
projectile loading means for loading a projectile in the opening in the front face while the rear face is engaged in line contact with the front face,
pumping means for pumping a liquid propellant into the combustion chamber as the combustion chamber is formed by rearward movement of the rear face whereby ullage in the combustion chamber is avoided, and wherein the projectile loading means include a projectile-carrier assembly having a carrier detachably connected to the projectile for transporting the projectile and wherein the rear face of the combustion chamber has an opening and the carrier is engaged in fluid sealing contact in said rear face opening and is disconnected from the projectile as liquid propellant is pumped into the combustion chamber during rearward movement of the rear face.

11. A gun as defined in claim 10 wherein the carrier and projectile have coacting ports and grooves in the sides of the carrier and projectile for permitting liquid propellant to enter between the back face of the projectile and a forward inner face of the carrier to separate the carrier from projectile.

12. A gun as defined in claim 10 wherein the carrier has a percussive igniter for igniting the liquid propellant.

13. A gun as defined in claim 10 wherein the carrier has a rear carrier rim and a flat formed on the carrier rim for orienting the projectile and carrier assembly with respect to other operating mechanism of the gun.

14. A gun as defined in claim 13 wherein the projectile and carrier have coacting positive locking means which can be engaged to extract the projectile-carrier assembly in the event of a misfire and wherein the flat on the carrier rim permits rotation of the carrier relative to the projectile to actuate the positive locking means.

15. A liquid propellant gun of the kind in which a projectile is loaded in the gun and liquid propellant is pumped into the combustion chamber behind the projectile and is ignited to fire the projectile from the gun,
said gun comprising a combustion chamber having a front face and a rear face,
said front face having an opening for the projectile,
said rear face being shaped complementary to the front face to engage the front face in line contact across the full surface of the front face except for the area of said opening,
moving means for moving one face relative to the other face into said line contact with the other face and for moving the one face away from the other face and into firing position,
projectile loading means for loading a projectile in the opening in the front face while the rear face is engaged in said line contact with the front face, and
pumping means for pumping a liquid propellant into the combustion chamber as the combustion chamber is formed by movement of the faces apart from each other to fill the entire chamber volume with liquid propellant simultaneously with the formation of the chamber whereby ullage in the combustion chamber is avoided and wherein the front face of the combustion chamber is formed on the end of the barrel of the gun, said gun includes a reciprocating combustion chamber housing, the housing includes a forwardly extending portion having one inside surface slidable on and sealingly engaged with the outside surface of the barrel, and another inside surface of the housing forms said rear face of the combustion chamber.

16. A liquid propellant gun of the kind in which a projectile is loaded in the gun and liquid propellant is pumped into the combustion chamber behind the projectile and is ignited to fire the projectile from the gun,
said gun comprising a combustion chamber having a front face and a rear face,
said front face having an opening for the projectile,
said rear face being shaped complementary to the front face to engage the front face in line contact across the full surface of the front face except for the area of said opening,
moving means for moving one face relative to the other face into said line contact with the other face and for moving the one face away from the other face and into firing position,
projectile loading means for loading a projectile in the opening in the front face while the rear face is engaged in said line contact with the front face, and
pumping means for pumping a liquid propellant into the combustion chamber as the combustion chamber is formed by movement of the faces apart from each other to fill the entire chamber volume with liquid propellant simultaneously with the formation of the chamber whereby ullage in the combustion chamber is avoided and including a bolt assembly and wherein the rear face is a part of the bolt assembly and said bolt assembly includes a passageway extending through said rear face and interconnecting the pumping means and the chamber.

17. A liquid propellant gun of the kind in which a projectile is loaded in the gun and liquid propellant is pumped into the combustion chamber behind the projectile and is ignited to fire the projectile from the gun,
said gun comprising, a combustion chamber having a forward face and a rear face,
said front face having an opening for the projectile,
moving means for moving the rear face forward into line contact with the front face and for moving the rear face backward away from the front face and into firing position,
projectile loading means for loading a projectile in the opening in the front face while the rear face is engaged in line contact with the front face,
pumping means for pumping a liquid propellant into the combustion chamber as the combustion chamber is formed by rearward movement of the rear face whereby ullage in the combustion chamber is avoided,
a magazine containing a clip of projectile-carrier assemblies, a tank of liquid propellant, and the pumping means,

a rearwardly extending part of the barrel assembly which includes the front face of the combustion chamber, a reciprocating combustion chamber housing which includes the rear face of the combustion chamber, said housing having a forwardly extending part which has an inner surface slidable on and sealingly engaged with an outer surface of the rearwardly extending part of the barrel, port means in the housing, and a valve element of the pumping means of the magazine associated with the port means of the housing to control the flow of liquid propellant from the magazine to the combustion chamber through the port means of the housing.

18. A gun as defined in claim **17** wherein the valve element has high pressure seals on the valve element for preventing loss of fluid pressure out of the combustion chamber during firing whereby the high pressure seals are replaced each time a new magazine is connected to the gun.

19. A liquid propellant gun constructed to avoid ullage problems in the loading of liquid propellant in the firing chamber, said gun comprising, actuator means for placing the forward face of a firing chamber in line contact with the rear face of the firing chamber, loading means for loading a projectile carrier assembly in firing position in the bore of the gun while the front and rear faces of the firing chamber are maintained in line contact, pumping means for pumping liquid propellant into the firing chamber to displace one face of the firing chamber axially with respect to the other face of the firing chamber, separating means for separating the carrier from the projectile as liquid propellant is pumped into the firing chamber, retaining means for retaining the projectile in the forward face of the firing chamber and for retaining the carrier in the rear face of the firing chamber as these two faces are axially separated, and igniter means for igniting the liquid propellant in the firing chamber to fire the projectile out the barrel of the gun.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,803,975 Dated April 16, 1974

Inventor(s) Lester C. Elmore and Thomas M. Broxholm

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Page 1, after title, insert --Some of the inventions herein described were made (first reduced to practice) in the course of or under a contract with ARPA.-- Column 5, line 33, after "partition" insert --101--. Column 6, line 35, "pcks" should read --picks--. Column 8, line 14, "hwich" should read --which--; line 15, "tank" should read --tang--.

Signed and sealed this 29th day of October 1974.

(SEAL)
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