April 12, 1949. W. J. KROEGER ET AL 2,466,714

RECOILLESS FIREARM AND AMMUNITION THEREFOR

Original Filed May 20, 1944 4 Sheets-Sheet 1

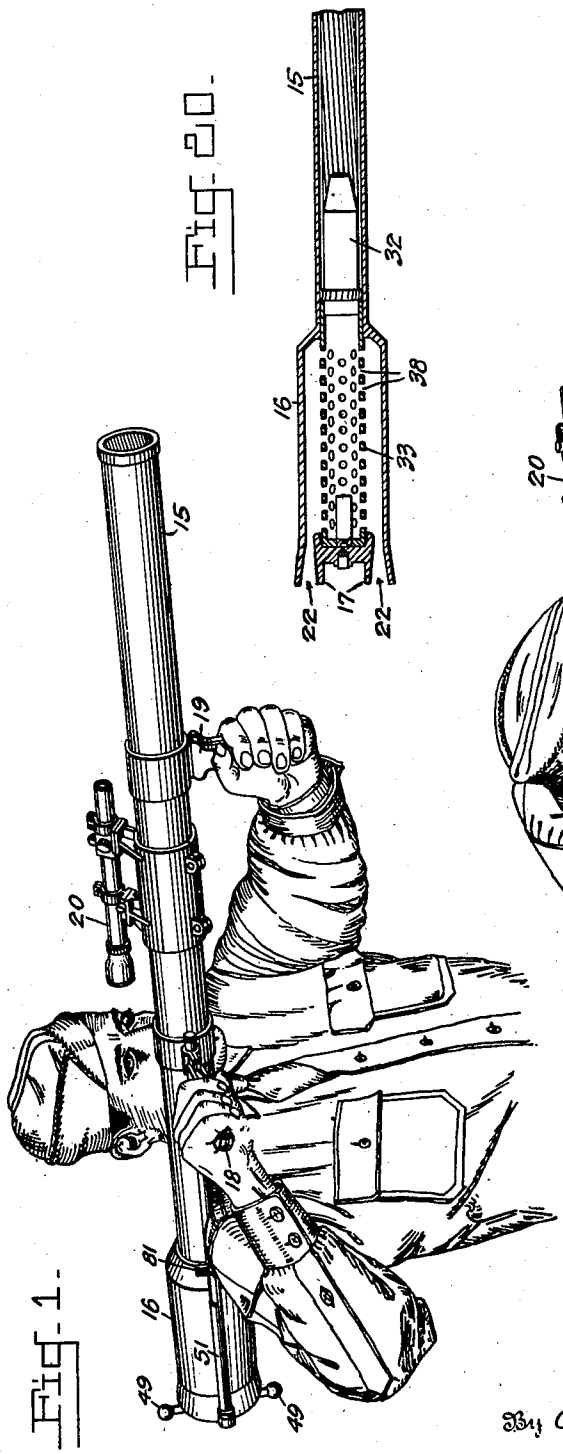

Fig. 1.

Fig. 2a.

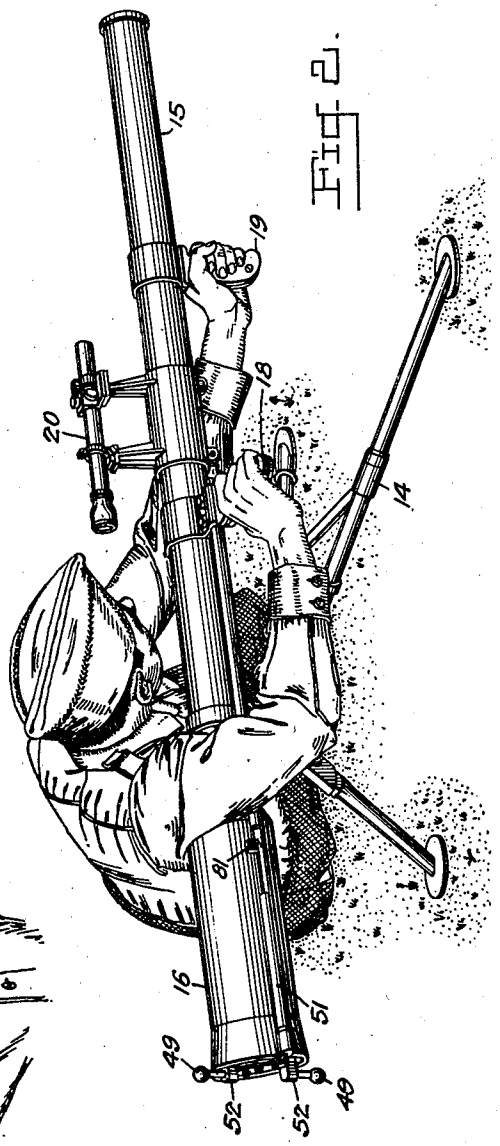

Fig. 2.

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RECOILLESS FIREARM AND AMMUNITION THEREFOR

Original Filed May 20, 1944 4 Sheets-Sheet 2

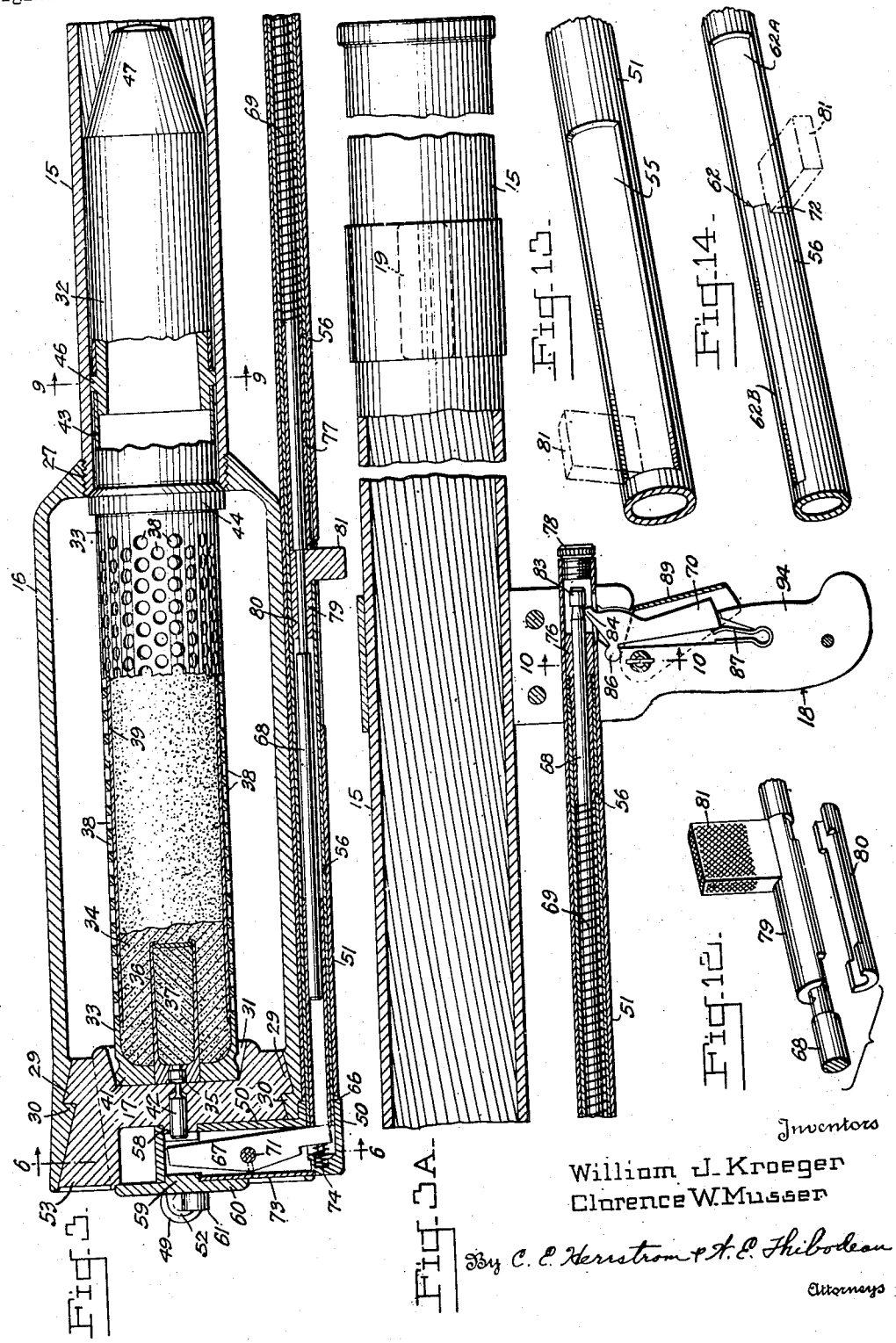

Fig. 1.

Fig. 1A.

Fig. 1B.

Fig. 1C.

Fig. 1D.

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RECOILLESS FIREARM AND AMMUNITION THEREFOR

Original Filed May 20, 1944 4 Sheets-Sheet 3

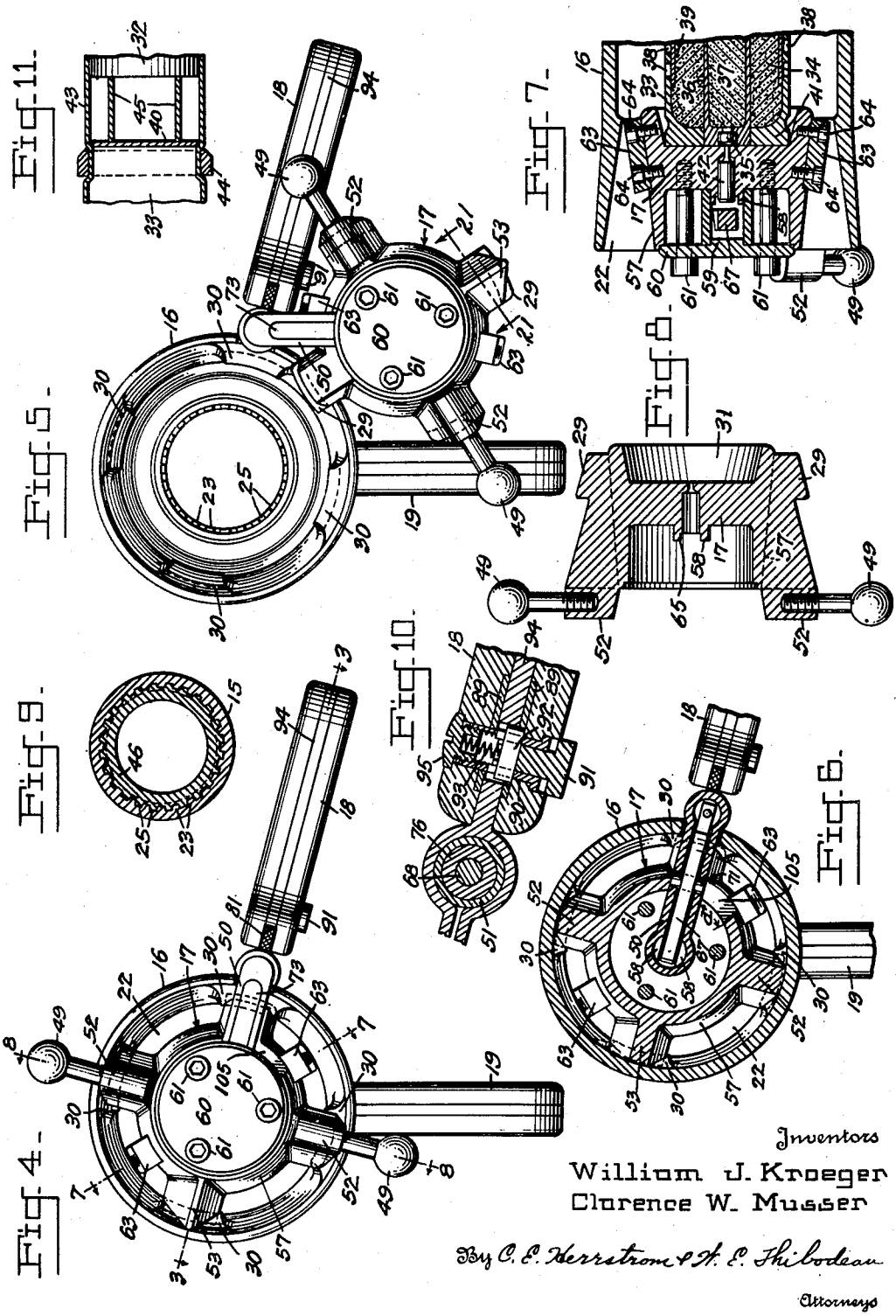

Fig. 11.
Fig. 7.
Fig. 5.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 6.
Fig. 4.

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RECOILLESS FIREARM AND AMMUNITION THEREFOR

Original Filed May 20, 1944 4 Sheets-Sheet 4

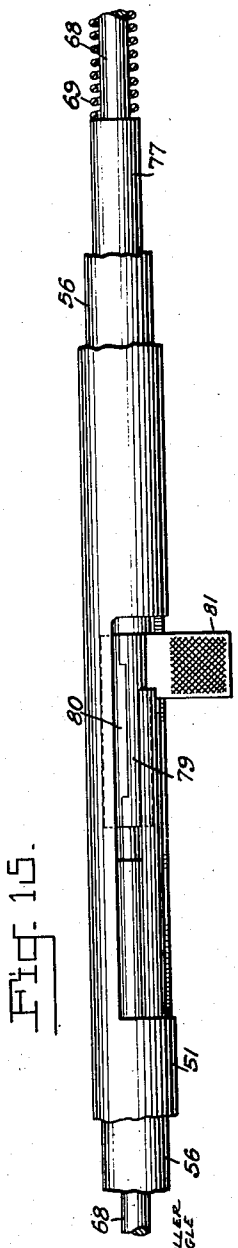

Fig. 15.

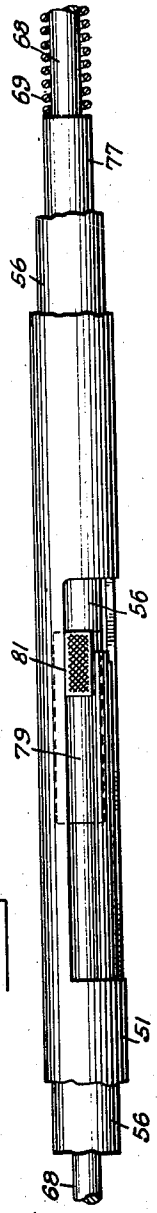

Fig. 16.

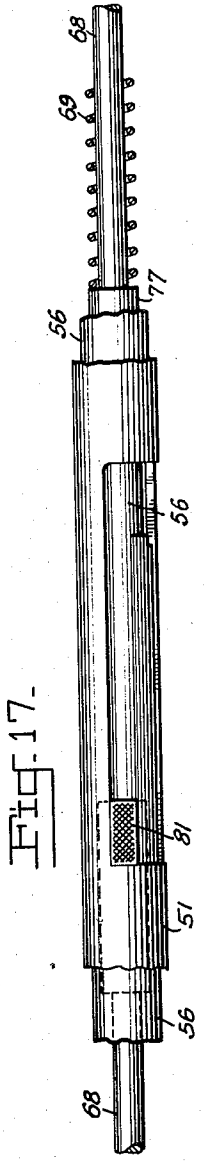

Fig. 17.

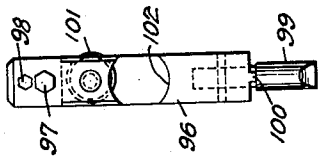

Fig. 19.

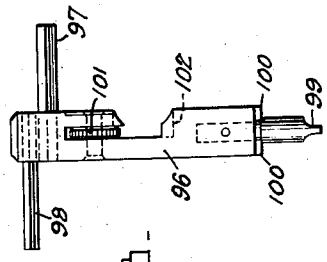

Fig. 18.

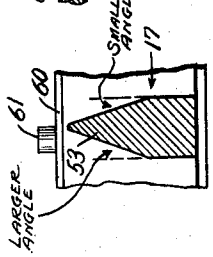

Fig. 21.

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Patented Apr. 12, 1949 2,466,714

UNITED STATES PATENT OFFICE

2,466,714

RECOILLESS FIREARM AND AMMUNITION THEREFOR

William J. Kroeger and Clarence Walton Musser, Philadelphia, Pa.

Continuation of application Serial No. 536,590, May 20, 1944. This application April 26, 1948, Serial No. 23,185

25 Claims. (Cl. 89—1.7)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

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The invention described in the following specification and claims may be manufactured and used by or for the Government for governmental purposes without the payment to us of any royalty thereon.

The present application is a continuation of application Serial No. 536,590 filed on May 20, 1944, now abandoned, in the names of William J. Kroeger and C. Walton Musser for "Recoilless firearms, ammunition therefor, and ballistic design thereof."

Our invention relates to firearms of the recoilless type and it has special reference to non-recoil guns wherein the forces of rearward reaction that result from projectile discharge are neutralized by forwardly acting counter forces simultaneously set up by the propellent charge's combustion.

Broadly stated, the object of our invention is to improve the design and extend the usefulness of recoilless guns wherein the named recoil neutralization is effected by a rearward escape of generated powder gas through openings or orifices in the gun's breech.

A more specific object is to lighten the weight and increase the firepower of recoilless weapons of the named open-breech type.

Another object is to evolve for such firearms a quantitative theory of ballistic design plus empirical formulae of proven accuracy.

A further object is to provide improved chamber and breech constructions for such recoilless guns and to make available new and improved ammunition for use therein.

A still further object is to provide improved designs for breech orifice nozzles, to facilitate orifice area adjustment and the securing of zero recoil at a desired performance level, and to neutralize gun twist with rifled barrels.

An additional object is to provide improved means for assuring substantially complete combustion of the powder within the gun's chamber, minimizing the blast to the rear, reducing the area which this blast covers, and minimizing rearward discharge of unburned powder and fragments.

A still additional object is to make possible the construction of a one-man recoilless firearm capable of shooting projectiles carrying considerable quantities of explosive through relatively long distances and yet not exceeding the weight limitations of an infantry weapon.

Other objects and advantages will become apparent as the disclosure and description hereof proceeds.

In constructing one recoilless firearm pursuant to foregoing we: (*a*) make the gun's chamber of substantially larger diameter than the ammunition cartridge case which fits therein; (*b*) support this cartridge case centrally in this enlarged chamber solely from the case's two ends; (*c*) provide in the gun's breech a rearwardly opening orifice of unique annular nozzle design and with ready adjustment for optimum area; (*d*) use wall metal for the cartridge case which is perforated throughout the case's length and circumference and which permits discharge of propellent combustion gases radially against the chamber's surrounding wall and thence rearwardly from the gun through the breech's annular orifice; (*e*) pre-engrave the projectile to permit its more ready passage through the rifled bore of the gun's barrel; and (*f*) so coordinate the breech and firing mechanism as to permit quick and convenient loading and firing.

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Our invention itself, together with illustrative embodiments thereof, will best be understood from the following description taken in conjunction with the accompanying drawings wherein:

Fig. 1 is a perspective view of a recoilless gun of 57 millimeter caliber which incorporates our inventive features and which is illustrated in position for firing from the shoulder of a user;

Fig. 2 is a similar showing of the same weapon supported from a tripod and there being aimed by a user;

Figs. 3 and 3A constitute a section on line 3—3 of Fig. 4 giving an enlarged view of the gun of Figs. 1–2 and showing the internal construction of that gun's barrel, chamber, breech details, ammunition and firing mechanism;

Fig. 4 represents the breech end of the same gun as viewed from the left of Fig. 3 with the breech block locked in the chamber where it constitutes the inner wall of an annular orifice;

Fig. 5 is a similar showing of the gun with the breech block withdrawn and swung down from the chamber and with the ammunition removed therefrom;

Fig. 6 is a section view on line 6—6 of Fig. 3 showing further details of the breech block and the tappet housing support therefor;

Fig. 7 is a section on line 7—7 of Fig. 4 through the orifice throat adjusting blocks plus other parts of the gun's breech and firing mechanism;

Fig. 8 is a partial section on line 8—8 of Fig. 4 through the breech block and the turning handles that are affixed thereto;

Fig. 9 is a section on line 9—9 of Fig. 3 through the gun's rifled barrel and the projectile's rotating band;

Fig. 10 is an enlarged section on line 10—10 of Fig. 3A through the trigger handle's safety

button and the hammer's spring retainer and housing;

Fig. 11 is a sectional showing of the cartridge case's front stop shoulder and powder-retaining disc;

Figs. 12–13–14 are enlarged showings of the hammer's split safety fixture plus the slotted hammer and hinge housing tubes therearound;

Figs. 15–16–17 are further views of the hammer and hinge housing tubes showing the safety lever in three different positions;

Figs. 18–19 illustrate a multi-purpose tool useful for assembling and disassembling the weapon;

Fig. 20 shows the recoilless gun's internal construction in simplified schematic form; and

Fig. 21 is a section view on line 21—21 of Fig. 5 showing further details of the breech block's vanes.

In the accompanying description the terms "forward" and "rearward" refer to longitudinal motion respectively toward the represented gun's muzzle and toward that gun's breech; and the terms "clockwise" and "counterclockwise" refer respectively to right hand and to left hand rotation about the gun's axis as viewed from the rear or breech end.

The complete recoilless gun

Our inventive improvements are here illustratively disclosed as being incorporated in a military weapon of 57 mm. caliber capable of a completely recoilless firing of projectiles weighing nearly 3 pounds at muzzle velocities of over 1200 feet per second. This gun's over-all length is only 60.82 inches and its total weight is less than 40 pounds. It is designed for carrying and use by one man and when held in the position shown by Fig. 1 may without danger or discomfort be fired from the user's shoulder with great accuracy and high military effectiveness; it may also be mounted on a light tripod of the character shown at 14 in Fig. 2 and there also aimed and discharged with remarkable accuracy and firepower.

As the description proceeds it will become apparent that our improvements may also be applied to firearms of sizes, characters and shapes other than the one here disclosed and that the represented 57 mm. open-breech weapon thus has been chosen only to illustrate and not to limit the inherently wide application and scope by which these improvements are characterized.

The illustrative recoilless firearm here shown consists of a barrel 15; an enlarged chamber 16 secured to the rear of this barrel; a breech block 17 (see Figs. 3–4) partially closing (see Fig. 20) the rear of the chamber; a trigger handle 18 for the user's right hand by which firing of the weapon is controlled; a barrel handle 19 for the user's left hand by which training on the target is aided; and a sight 20 for aiming the gun in conventional manner.

This sight 20 may be of a telescopic or other type capable of accommodating ranges from a minimum of a small number of yards up to a maximum of about 3000 yards. It may be mounted on the gun's barrel in any suitable manner; as directly over the barrel's top, as shown in Fig. 2, or sufficiently inclined from that top position to make aiming more convenient, as indicated by Fig. 1.

As here represented, the gun's trigger and barrel handles 18 and 19 are suitably clamped around the barrel 15 at the spaced locations shown by Figs. 1–2 and with the angular relation further indicated by Figs. 4–5–6.

The barrel, chamber and breech

As here shown, the gun's barrel 15 has an inside diameter of 57 millimeters. The bore of this barrel is rifled to secure the usual gains in accuracy and range which a spinning of the projectile in flight makes possible. The rifling represented has a right hand twist and utilizes the twenty four lands 23 with intervening grooves 25 which Figs. 5 and 9 show. Depending upon projectile stability needs, steepnesses of twist other than that illustrated may obviously be chosen; and twists in the left hand direction may also be employed with equal effectiveness.

Smooth-bore barrels are, of course, useable by recoilless firearms constructed in accordance with our invention; however, the accuracy and range characteristics of smooth-bore barrels are so far inferior to proven performances with rifled barrels that the latter are highly to be preferred for most practical weapons of our improved non-recoil type.

As here shown, the gun's chamber 16 takes the form of an enlarged cylinder which is affixed at its forward end to the rear of barrel 15 in any integrally secure manner, as by the aid of screw threads 27. If desired this connection may be rendered more permanent by a brazing of metal (not shown) around the entire circumference of the juncture. Such brazing constitutes a gas-tight seal which prevents damage to the threads from powder leakage therethrough; it also prevents relative turning between the barrel and chamber.

As the drawings show, the gun's breech block is a "spider-like" element removably secured within the rear end of chamber 16 and constitutes only a partial closure therefor (see Fig. 20). The breech block is actually an apertured supporting member on which are fixed certain vanes 52—53 whose form and function will later be described in detail. It takes the form of a cylindrical block 17 which is radially spaced from the chamber wall in a manner to form a substantially annular orifice or venturi that leads from the chamber's interior to the rear exterior of the gun. In Fig. 20 a section of this annular orifice is shown at 22.

Four locking lugs 29 (see Figs. 3–4–5–6) extend radially from this central breech block 17 in "spider-like" fashion and interfit with mating protrusions 30 (see Figs. 3 and 5) on the chamber wall interior. These mating parts have the form best shown by Fig. 3, and when engaged as in Figs. 3, 4 and 6 they securely lock the breech block 17 within the rear of the chamber.

The chamber wall spaces which circumferentially separate the locking protrusions 30 have a diameter larger than the maximum for the breech block lugs 29, and this relation enables free longitudinal movement by those lugs through the spaces named. This movement is utilized in inserting the breech block into the chamber and also in withdrawing it therefrom, all in a manner to be described presently.

When inserted and locked within the chamber as shown in Figs. 3–4–6 this breech block 17 constitutes a firm support for the ammunition which it helps to position within the chamber. The steel of its central core structure is of sufficient thickness and strength to withstand with a factor of safety of well over 3 the maximum rearward thrust exerted thereon during firing.

The complete round of ammunition

Cooperating with the barrel, chamber and

breech structure just described is ammunition having the unique character shown in Figs. 3, 7 and 11. As here illustrated, the complete round of this ammunition includes a projectile 32 inserted into the rear bore of the barrel 15; a cartridge case 33 communicating with the rear of projectile 32 and centrally supported within the cylindrical chamber 16 by the barrel at the front and by the breech block 17 at the rear; a quantity of propellent powder 34 within the cartridge case; and powder igniting means shown in the form of a primer 35 and booster 36.

As here represented, this ammunition's cartridge case 33 has a diameter which is substantially less than that of the surrounding chamber 16; it being shown as approximately the same as the barrel's bore and only about half the chamber diameter. The cartridge case wall preferably is of durable metal, such as steel or brass, or of other material. A prerequisite for the case is that it be of sufficient thickness and strength as to remain intact during firing.

Perforating this wall metal are a large number of relatively small openings 38 distributed throughout substantially the entire length and circumference of the case in the uniform manner indicated. These case wall openings 38 constitute an aggregate area which is nearly ⅓ of the total surface area of the represented cartridge case 33. This aggregate opening area is roughly six times the bore area of the gun's barrel.

For preventing the propellent powder 34 from falling out of these openings during loading and prior to firing, and for acting as a diaphragm capable of withstanding adequate pressures before rupturing, a thin layer of frangible material 39 such as a heavy paper is placed inside the perforated case 33 between the case wall and the powder. Such a lining disintegrates early in the combustion cycle of the propellent powder and thus enables escape of combustion gases and burning powder radially through the openings and into the chamber space immediately surrounding the case.

The unique case construction shown permits the named radial expansion of powder gases into the surrounding chamber without rupture of the metal between wall openings 38 or other damage to the case. In open-breech guns of the type here considered such security against failure of this kind is exceedingly important for were the breech orifice to be blocked by metal or other obstructions recoil neutralization would be violently upset and dangerously high pressures would occur.

The propellent powder represented at 34 substantially fills the entire volume of the cartridge case interior that is behind a forward retaining disc 40 (see Fig. 11). That disc preferably is of frangible material such as cardboard about $\frac{3}{32}$ inch thick. Its purpose is to prevent the propellent powder from occupying the cartridge case in the extreme forward portion where no wall openings are provided and thereby to safeguard the unperforated area of the case wall against rupture upon firing.

We have used conventional double base powders and have found them to exhibit satisfactory burning characteristics at the relatively low chamber pressures employed by recoilless guns of the improved type here disclosed. Typically, such pressures for the particular 57 mm. weapon shown may be of the order of 5000 pounds per square inch.

Such operating pressures are far below those encountered in conventional closed-breech guns

where 50,000 pounds per square inch is typical for military rifles and other small arms, and around 30,000 pounds per square inch is characteristic of larger caliber (above 0.60) firearms. As will become more evident presently, a proper choice of propellent powder is important to the most effective functioning of our recoilless firearm.

For igniting the propellent charge 34 use may be made of any suitable primer and booster combination such as that shown at 35—36 in Fig. 3. Primer 35 may satisfactorily be of a standard percussion type such as is used in ammunition for caliber .50 firearms of conventional design. This primer serves to ignite a larger charge of booster explosive 37. By combustion of this booster charge the entire mass of propellent powder 34 is ignited.

Both the primer 35 and the booster 36 are carried by the cartridge case head 41 in the central position shown where the attachment is rendered mechanically secure by force fitting or other suitable expedient. In this position the primer 35 is engageable by a firing pin 42 protruding through the center of the breech block 17 and there actuated by firing mechanism later to be described.

In the loaded position shown this cartridge case head 41 is engaged by a mating recess 31 in the breech front. This recess 31 flares outwardly (see Figs. 3 and 8) toward the front more conveniently to receive the case head during loading. By its engagement with the head, the rear of cartridge case 33 is centrally positioned within chamber 16 and the entire case is restrained against backward movement.

A similar central positioning of the forward end of the cartridge case is effected by protrusion of an extreme front section 43 thereof into the bore of barrel 15. Restraining this forward protrusion at the point where the case head 41 snugly fits against breech block 17 is a stop shoulder ring 44 which encircles and is mechanically secured to the forward portion of the case 33, as by a shrink fit of the character indicated in Fig. 11. The front face of this stop ring may either be square for direct contact with the rear of barrel 15 or have the rearward flaring shown.

This ring 44 restrains the cartridge case against longitudinal movement in the forward direction and thus insures that the case head will at all times hold the primer 35 in proper position for effective engagement by the gun's firing pin 42.

As here shown the ammunition's projectile 32 communicates with the front section 43 of the just described cartridge case and is suitably held therein by the represented "force fit" overlap connection which permits ready forward release of the projectile upon combustion of the propellent powder. In instances where the projectile may not extend completely back (see Fig. 11) to the cartridge case's stop ring 44, the desired positioning of the powder-retaining disc 40 just ahead of that ring may be maintained by any suitable spacer such as that shown at 45 in Fig. 11.

The represented projectile 32 makes use of a rotating band 46 (see Fig. 3) which is pre-engraved (see Fig. 9) to assure more ready passage of the projectile through the barrel 15's rifled bore. For the 57 mm. weapon here described, that band may satisfactorily be made of brass or other metal (such as gilding) about ¼ inch wide, and the pre-engraving thereof preferably is dimensioned to provide with the barrel's rifling a diametral clearance of the close order of about 0.005 inch. Clearances of this order assure positive

registration with the barrel's rifling; prevent objectionable yaw of the projectile while within the bore and at the instant of leaving the gun; and at the same time permit the desired free passage of the projectile through the rifled barrel upon combustion of the propellent charge.

In open-breech guns of the type here considered such free passage is exceedingly important for were the projectile to jam the rearwardly emanating combustion gases then would exert their full forward force on the weapon itself and bodily propel it forwardly as a rocket. Pre-engraving of the projectile minimizes this possibility.

Such pre-engraving makes still additional contributions to the represented open-breech weapon's practical performance. A cutting by the projectile of its own rifling grooves calls for a propelling force which is substantially increased and which also is subject to wide variations in absolute value.

The former feature requires comparable increases in recoil neutralizing force, attendant enlargements of the breech orifice area or thickenings of the cartridge case's inner lining, and marked reductions in the weapon's over-all efficiency; the latter feature makes complete recoil neutralization relatively more difficult and unreliable since large rather than small forces are being cancelled and since variations therein cannot be predicted.

Our represented pre-engraving of the projectile minimizes all of the stated difficulties and thus constitutes a significant feature of our complete firearm. Moreover, its resultant eliminations of pre-engraving pressure behind the projectile and of "swedging" erosion of the bore's lands makes reductions in barrel weight and increases in barrel operating life at once possible.

This illustrative projectile **32** has been represented as including an internal recess for carrying a quantity of high explosive charge (not shown) which may be detonated by suitable means such as a time or other fuse (not shown) installed in the projectile's nose **47** (or base) in well-known manner. Optionally the projectile might also consist of a solid mass of metal and in that event the illustrated recess for high explosive would be dispensed with. In either case the axial and transverse moments of inertia and the distance from the nose to the projectile's center of gravity can be so coordinated with the firing velocity and barrel rifling as to assure stability during flight.

Yaw observations made and other firing data obtained by us confirm that projectile **32** is stable when fired from the illustrated barrel **15** having the represented rifling twist. In order to permit use of the projectiles having lower inherent stability characteristics, it is merely necessary to increase the twist of barrel rifling to some steeper order. Through a proper coordination of the factors earlier named our recoilless firearm here disclosed thus may make satisfactory use of projectiles of a wide variety of forms, types and shapes.

The annular orifice and adjustable nozzle

Recoilless firearms of the open-breech type here considered neutralize the forces of rearward reaction by forwardly acting counter forces. In our improved weapon these counter forces are produced by acceleration of the rearwardly escaping generated powder gases with an accompanying pressure gradient within the chamber

and venturi. Therefore the pressure forces rearwardly acting against the obstructions presented by the breech can be counteracted by the forwardly acting pressure forces acting on the small annular forward portion of the chamber **16**, the forwardly acting drag forces of the projectile **32** in the rifled barrel **15** and by the forwardly acting force component produced by the pressure of expanding gases in the conical and divergent portions of the earlier indicated annular orifice **22** (see Fig. 20) between the gun's breech block **17** and the rear wall of chamber **16** wherein this block is secured.

As is most clearly illustrated by Figs. 4–5–6, this annular orifice extends all the way around that block's central core or hub and is obstructed only by the four radial vanes **52—53** which commence centrally from the common hub portion and terminate at their outward extremities in the breech locking lugs **29** (see Figs. 4–5–6). All circumferential space separating lugs **29** thus constitutes the named annular orifice **22** which leads from the interior of chamber **16** rearwardly to the exterior of the gun.

Upon ignition of the propellent powder **34** and the resultant discharge of projectile **32** forwardly out of barrel **15**, there is expelled through the perforations **38** of cartridge case **33** combustion gases which are projected radially against the surrounding chamber wall and thence rearwardly out of the chamber through the annular orifice now being described. By thus acquiring momentum opposite to that of the forwardly moving projectile the explosive gas thus expelled sets up the aforesaid counter forces which tend to neutralize recoil.

In our improved weapon we supplement this momentum effect by making the annular breech orifice of the represented "nozzle" shape indicated by Figs. 4, 6, 7 and 20. Starting with a relatively narrow radial width at its front or throat, the annular orifice flares outwardly (see Fig. 20) toward the rear with a total angle of spread of approximately 15 degrees. The exact value of this angle is chosen to yield the optimum of forward force component due to an expansion of the powder gases in passing rearwardly through the orifice as earlier explained. Too narrow an angle is found to cut down the magnitude of this forward force component, while if the angle is made too wide the gases seem no longer to keep contact with the steepness of wall separation and much of the desired nozzle effect again is lost.

For maximum effectiveness it would be desirable to extend the annular orifice to a substantial axial dimension but practical considerations show that acceptable performance is achieved when the nozzle orifice has the relatively short length which our drawings indicate (see Figs. 3, 7 and 20). Thus we prefer to select for the nozzle an axial length which gives a rear or discharge area of approximately four times the orifice's front or throat area. Dimensions other than that shown may of course be utilized with varying degrees of relative effectiveness.

In our achievement of complete neutralization of recoil we find that there exists an optimum ratio between the bore area of the gun and the throat area of the breech orifice. This ratio is dependent primarily upon the amount of expansion obtained in the venturi **22** and to a lesser extent upon such factors as the relative weights of the powder and projectile. In a firearm of the annular orifice type here disclosed this ratio

for zero recoil will lie within the range of about 1.35 to about 1.70.

Our improved weapon includes provision for adjusting this ratio to the optimum value which during actual firing does in fact produce zero recoil. In the illustrative arrangement disclosed this provision takes the form of a pair of orifice blocks **63** affixed to flattened portions on opposing sides of the inner nozzle wall and there firmly held by any suitable means such as the represented bolts **64** (see Fig. 7) with countersunk heads. While occupying such a portion of the total orifice area as is needed to provide the necessary adjustment these blocks **63** do not alter the basic nozzle shape thereof, and hence they constitute a particularly efficient means of effecting the required adjustment.

The maximum throat area is of course realized when both blocks **63** are removed; hence the annular orifice is designed to afford a throat area large enough to meet the maximum requirements under that condition. Applying the figures earlier stated, this might give a bore-area to throat-area ratio of the 1.35 lower limit. To change this ratio to its other extreme of the named 1.70 maximum, it is merely necessary to install at **63** orifice blocks of size sufficient to cut down the total throat area by the requisite amount; and to obtain ratios of intermediate values there may be substituted adjusting blocks **63** of varying intermediate size.

In practice we find it convenient to mark on each block the particular value of bore to throat area ratio which its use (along with a companion block of the same dimension) will give. Thus, one set of blocks will be marked 1.58; another 1.60; a third 1.62; and so on.

Choice of the exact block size is most effectively determined by trial firings in a pendulum or other gun suspension which is free to swing and thereby indicate the presence, direction and magnitude of recoil should same exist. In the illustrative 57 mm. weapon represented, zero recoil is found to require the use of a pair of blocks which give a bore area to throat area ratio of the order of 1.60. With such adjustment the nozzle throat has a total area which is approximately one tenth of the cartridge case's "perforation" area.

Neutralization of rotational reaction

Firearms with rifled barrels experience a rotational reaction by virtue of the spinning motion that firing imparts to the projectile. In the particular gun shown barrel **15**'s right hand twist gives clockwise rotation to projectile **32** upon forward movement thereof through the barrel, and this right-hand acceleration of the projectile's mass imparts counterclockwise torque of equal magnitude to the barrel.

Our improved weapon includes provision for neutralizing such reactive torque by causing the explosive gases which rearwardly discharge through the annular breech orifice **22** to impart to the weapon counterbalancing torque of the same magnitude as that which the rifled barrel imparts to the projectile. This provision is effected by so specially shaping the rear tailpieces of the breech block vanes **52—53** that the gases passing through orifice **22** have angular momentum imparted thereto.

Each of these breech block vane tailpieces tapers in the general manner shown by Fig. 27 from a maximum cross section beneath locking lug **29** (see Figs. 3–5) rearwardly toward a minimum and much narrower width at the rear extreme thereof (see Figs. 4–5–6). If this taper were the same on both sides of each tailpiece, the discharge of powder gases there past would exert no rotative force in either direction, but instead the side force components set up by the expanding gases would be the same in both directions and hence completely counteract one another.

To obtain the desired torque neutralization we modify the tailpiece flaring to the extent indicated by Figs. 4–5–6 and 27. There it can be seen that the angle on the one side of each tailpiece differs from the angle on the other side in the proper amount and direction to give the gases a counteracting spin about the gun axis. The effect is to impart to the axes of breech orifice openings **22** small angular displacements (all in the same rotative sense) with respect to the main axis of the gun's barrel **15** and chamber **16**.

In consequence the sides of these vanes having the smallest angle have imparted thereto a stronger side or tangential thrust from the expanding gases than do the opposite vane sides, and there thus is imparted to the breech block a torque counteracting that applied by the projectile. Only the relatively small degree of angular unbalance indicated is found sufficient to make the thus imparted torque of the same magnitude as the barrel **15** imparts to the projectile **32** in advancing it through the rifled bore.

During firing the breech block **17** transmits this neutralizing torque to the chamber and thence to the barrel, and in this way all forces of rotational reaction are neutralized in a very simple yet highly effective manner. In the illustrative weapon shown the combustion gases that flow rearwardly through breech orifice openings **22** have imparted thereto a counterclockwise spin which is opposite to the clockwise spin given by the gun's right hand rifling to the forwardly fired projectile **32**. As the vane structure of the nozzle-forming portion of the breech block **17** is asymmetric in relation to the gun's axis for each venturi opening, a different amount of expansion tends to occur for opposite sides of each venturi for axial gas flow. Therefore, the center line of the gas flow through each nozzle is tangentially diverted in a circular pattern about the axis of the gun. The accompanying gas "reaction" torque exerted on the gun is clockwise and thus neutralizes the counterclockwise projectile "reaction" torque received by the barrel **15**.

Were the gun barrel to be rifled with a left hand twist rotational reaction could be neutralized in exactly the same way merely by shaping the breech vanes in the opposite sense.

The breech block carrier and lock mechanism

Explanation has already been given of how the breech block **17** is secured in the rear of chamber **16** by the aid of that block's locking lugs **29** and the mating protrusions **30** on the chamber interior. In the locked position represented by Figs. 3, 4 and 6, this support is all that is needed to hold the breech block in place, and it is fully adequate to restrain the maximum chamber pressures which combustion of the propellent charge **34** sets up.

To facilitate loading, and removal of the cartridge case **33** after firing, provision is made for unlocking this breech block **17**, rearwardly withdrawing it from the chamber **16** and swinging it out of alignment with the chamber interior to some downward position such as that shown in Fig. 5. Aiding these actions is an operating member which illustratively takes the form of a pair

of handles 49 which protrude from the breech block, a radial support member shown in the form of a tappet housing 50 which extends into that block's center, and a lateral support member shown in the form of a hinge housing 51 (see Fig. 3) which interconnects the radial member 50 with the outside of the gun's chamber 16. These elements constitute mechanism by which the breech block continues to receive support from the gun after it has been withdrawn from the chamber.

The named operating member represented in the drawings by handles 49 protrudes in the manner shown from radial vanes 52 which extend rearwardly from the breech block 17 by a distance somewhat greater (see Fig. 3) than do the remaining two breech block vanes 53 (see Fig. 5). By these handles an operator may rotate the breech block through the small angular distance indicated at *d* in Fig. 6. In the gun here shown this range of angular movement is of the order of 35 degrees.

Clockwise rotation serves to engage the breech block locking lugs 29 behind the mating protrusions 30 of the chamber and thereby secure the breech block therein as earlier explained; counterclockwise rotation moves the locking lugs out of engagement with the chamber protrusions and into the circumferential regions between protrusions. In the latter position the breech block 17 is free for rearward withdrawal from the chamber.

Serving to support the breech block upon such withdrawal is the radially disposed tappet housing 50 earlier mentioned. This housing is attached at its outer end to a pivot tube or hammer housing sleeve 56 sliding and turning in the stationary hinge housing or support tube 51 earlier mentioned as being fixed to the outside of chamber 16; from this attachment the radial tappet housing extends through a cut away portion in a rear rim 57 (see Fig. 6) of the breech block to that block's center where the gun's firing pin 42 is mounted (see Fig. 3).

There circular openings in the front and rear of this radial member 50 accommodate opposing bosses 58 and 59 (see Fig. 3) projecting from the breech block and from a cover plate 60 therefor. This cover plate is secured to the block by the aid of three bolts 61 which pass through the plate and into tapped openings in the block metal thereby holding the plate firmly in a mating recess in the block's rear rim 57.

The rotatable connection thus established permits the earlier named angular movement of the breech block 17 with respect to the chamber 16, and also with respect to the tappet housing 50 which extends into the block's center from the chamber's outside. In this way application of clockwise turning force to handles 49 effects locking of breech lugs 29 behind the mating protrusions 30 of chamber 16; and application of counterclockwise turning force disengages those lugs from the chamber protrusions and thus frees the breech block for rearward withdrawal from the chamber. Both of these turning movements are limited in their extent by the sides of the represented (by Figs. 4–5–6) opening 105 in the wall of the rear breech rim 57.

In a weapon having the represented right hand rifling, the gas forces applied as earlier explained to neutralize torque reaction exert clockwise turning effort on the breech block and thereby maintain the locked position thereof during firing. Were the gun to be rifled with left hand twist, then the locked position of the breech block should of course be at its counterclockwise limit of turning movement.

The earlier named hinge housing sleeve 51 is secured to the outer wall of chamber 16 (see Fig. 3) by brazing or other permanent form of attachment. This hinge housing is continued forwardly to the trigger handle 18 (see Figs. 1–2–3–3A) and within it the smaller diameter hammer housing sleeve 56 is carried (see Figs. 15–16–17) in a manner permitting both radial and lengthwise movement. This form of carriage permits the affixed tappet housing 50 (see Fig. 3) to be withdrawn rearwardly with respect to the hinge housing 51 and also to be rotated with respect thereto.

Once, therefore, the breech block 17 has been disengaged from the chamber protrusions 30, application of rearward force to handles 49 causes the breech block 17, tappet housing 50 and hammer housing 56 all simultaneously to be moved back away from the rear of chamber 16. The range of this backward movement is sufficient to allow complete clearance of the breech block with respect to the chamber, and when this condition is realized the breech block and tappet housing may both be swung downwardly to the position shown in Fig. 5.

Here the entire interior area of the chamber 16 is unobstructed in a way permitting ready insertion of the projectile and cartridge case 32—33 into the gun or ready withdrawal of a fired cartridge case from the gun's chamber.

To reinsert the breech block into the chamber it is merely necessary to swing the tappet housing 50 clockwise and upwardly about its hinge mounting in housing 51; position the breech block in its counterclockwise limit of travel with respect to housing 50; thrust the so petitioned breech block forwardly into the open end of chamber 16; and finally turn the breech block to its clockwise limit of rotation in which the locking lugs 29 thereof engage with the chamber's mating protrusions (see Fig. 3).

Close fitting of the radial tappet housing 50 against the end of the hinge housing 51 when the breech block 17 is locked within the gun's chamber may be secured in any desired manner such as by the aid of shims of the type shown at 66 in Fig. 3.

The firing mechanism

For igniting the ammunition's propellent charge 34 at the will of an operator, use may be made of any suitable firing mechanism either electrical (not shown) or mechanical (here disclosed). Here represented by way of illustration is a unique mechanical type of firing mechanism by the aid of which an operator may fire the weapon by a simple squeezing of the trigger handle 18. In the disclosed arrangement the firing pin 42 carried by the gun's breech block 17 (see Fig. 3) receives through a tappet 67 a firing blow created by the rearward movement of a rod-shaped hammer 68. The force incident to this rearward movement originates in a compression spring 69 and is made available for firing the gun when a trigger 70 protruding from the front of trigger handle 18 is depressed.

The just named tappet 67 (see Figs. 3 and 6) is mounted on a rocker pin 71 within the radially disposed tappet housing 50. As earlier described this radial member 50 also constitutes the support for the breech block 17 when withdrawn from the weapon's chamber 16; serving to close the

housing's back is a removable cover 71 held in place by an overlapping of the breech block cover plate 60. A tappet retractor spring 74 urges the outer end of this tappet to the forward travel limit shown in Fig. 3, and in that condition the inner end of the tappet is separated from the rear of firing pin 42 by the substantial clearance which Fig. 3 also shows.

The illustrated hammer 68 takes the form of a long, slender rod of steel or other suitable metal slidably contained (see Figs. 15–16–17) within the housing sleeve 56 earlier described as constituting a support (see Fig. 3) for the outer end of the radial tappet housing 50. As earlier explained, this housing sleeve or pivot tube 56 is rotatably and slidably contained within the outer hinge housing tube 51, which hinge housing is fixed (as by brazing) to the outside of chamber 16. That hinge housing, in turn, extends from the weapon's chamber to and slightly past the trigger handle 18 where the forward end thereof is closed by a plug 78.

From Figs. 3–3A (and Figs. 15–16–17) it will be seen that the companion hammer housing 56 likewise extends within the stationary hinge housing 51 from the rear location of tappet housing 50 to the forward location of trigger handle 18. Here the housing or pivot tube 56 terminates in a spring retainer 76, taking the form of the represented sleeve (see Fig. 3A) attached to the tube end by a thread connection.

Figs. 15–16–17 show that the inside diameter of this hammer housing 56 is somewhat larger than the outside diameter of the hammer rod 68 which it surrounds, and the earlier named hammer spring 69 is carried (see Figs. 3–3A) within the space thus made available. The forward end of this hammer spring abuts against the retainer 76, while the rear end of the spring exerts force against a spacer sleeve 77 (see Figs. 15–16) also slidably carried between the central hammer 68 and the housing sleeve 56 which surrounds it.

Adjacent to this spacer 77 on the side opposite to the spring is a reduced diameter section of the hammer 68 and surrounding it is a split safety fixture made up of two parts 79—80 having the mating character shown in Fig. 12. These two parts are housed within the hammer tube 56 for restricted slidable and rotative movement, and they also permit the hammer 68 to move axially therethrough along the hammer's reduced diameter portion.

Radially protruding from part 79 is a safety arm 81 which extends through registering slots 62 and 55 in the concentrically disposed hammer and hinge housings 56 and 51, respectively (see Figs. 3, 15–16–17), to the outside for manipulation by the operator. The named slots 62 and 55 have the character illustratively shown in enlarged Figs. 13–14, and during cocking and firing of the hammer rod 68 these slots cooperate with the safety arm 81 in a manner to be explained presently.

The slot 55 in the outer or hinge housing 51 (see Fig. 13) has the substantial width later named and is of length greater than the axial distance through which the hammer 68 and safety arm 81 move during cocking and firing. The cooperating slot 62 in hammer housing 56 is comprised of two parts identified as 62A and 62B (see Fig. 14). This slot 62 is wide at its front 62A and narrow at its rear 62B and has on the narrow side thereof a total length somewhat greater than that of housing 51's slot 55; the wide region of this hammer housing slot is sufficiently long to enable the safety fixtures 79–80 to be inserted therethrough for assembly around the reduced diameter portion of hammer 68.

This hinge housing slot 55 (see Fig. 13) and the hammer housing slot 62 at its widest section (see Fig. 14) both have a total circumferential width of somewhat more than 90 degrees. In cooperation with safety arm 81 these two slots serve to restrain the downward swinging movement of the tappet housing 50 (see Fig. 5) to an angle of only slightly more than that 90-degree limit.

Under the "after loading" conditions represented in Figs. 3–3A and 15 the hammer 68 is cocked to the forward position where a latch head 83 thereof is advanced past trigger 70's sear 84; the hammer spring 69 is compressed between hammer housing 56's forward retainer 76 and the rearward spacer 77; that spacer abuts parts 79–80 and through them is held against rearward movement by engagement of safety arm 81 with the hammer housing 56's short lower recess (see Figs. 14 and 15); and in consequence the hammer 68 has none of the spring's compressive force exerted thereon.

To "arm" the hammer in readiness for firing, the safety arm 81 must be pushed forward against the compression of spring 69 to clear the recess 72 of the short slot 62A in tube 56 (see Fig. 14) and rotated upwardly into alignment with hammer housing 56's long slot 62B as shown in Fig. 16. This permits the spring 69 and spacer 77 to push the safety fixture 79–80 backward to the point where the rear thereof abuts the larger diameter of the hammer 68. That hammer now receives the rearward force of the spring and pulls latch head (see Fig. 3A) 83 against the trigger sear 84.

Under these conditions a depression of the trigger 70 will release the hammer allowing the compressed spring rapidly to move it backwardly along with spacer 77 and the safety fixture. By this movement the safety arm 81 moves in the narrow slot 62B of housing tube 56 to the rear limit thereof. This rear or "as fired" limit of the safety lever is shown by Fig. 17.

It is reached just before the end of hammer 68 has contacted tappet 67, and at that point the spring's compressive force is removed from the hammer. The momentum of acquired motion causes the hammer to continue to move back through safety fixture 79–80 and by striking the outer end of tappet 67 to impart a blow to the firing pin 42 and thereby detonate primer 35.

To recock the hammer in preparation for the firing of another round, the breech block 17 is by counterclockwise rotation disengaged from the chamber 16 and rearwardly withdrawn by handles 49. Tappet housing 50 transmits this rearward movement to the hammer housing 56 and pulls retainer 76 backward in the stationary hinge housing 51. Safety arm 81, now abutting (see Fig. 13) the rear of hinge housing 51's slots 55, restrains the spacer 77 from rearward movement, and in consequence, the hammer spring 69 now becomes compressed.

By this rearward movement the narrow slot 62B in hammer housing 56 is drawn past the safety arm 81 and to a position of housing 56 where that safety arm is in the area of housing 56's wide forward slot 62A. Incident thereto is a complete clearance of the breech block 17 from the end of chamber 16, and a resultant freedom of swinging movement of this block downwardly to the position shown in Fig. 5.

Such a swinging of tappet housing 50 rotates the hammer housing 56 counterclockwise in the

stationary hinge housing 51. During this rotation of this hammer housing 56, the safety arm 81 continues to abut the rear of hinge housing 51's slot 55, as shown dotted by Fig. 13 and thus the recess 72 in the short slot 62A of housing 56 (see Fig. 14) is brought into alignment with that arm. Release of breech block withdrawing force now allows the hammer spring 69 to pull the hammer housing 56 forward and thus re-engage this housing's short slot 62A recess with arm 81, as shown by Fig. 14.

Subsequent swinging of the breech block and tappet housing 50 upwardly (clockwise) into alignment with the weapon's chamber rotates housing tube 56 and safety arm 81 clockwise in the stationary hinge housing 51. Here the breech block may be forwardly re-inserted into the end of chamber 16 by movement which carries hammer housing 56, safety arm 81 and the compressed spring 69 all forward in the stationary hinge tube 51.

By this forward movement the firing mechanism is returned to the original or "after loading" condition of Figs. 3 and 15 with which this description started.

Firing pin, loader's and trigger safeties

The gun operator's or "loader's" safety has already been described in part. It utilizes the safety arm 81, which at the end of each cocking occupies the "after loading" position shown in Figs. 3 and 15. With the safety arm 81 in this position pulling of the trigger 70 is ineffective for releasing the hammer, and no firing of the weapon is possible.

Before the weapon can be fired, it is necessary for the loader of the gun to push safety arm 81 forward out of housing tube 56's slot recess (see Figs. 14–15) and rotate it counterclockwise into alignment with that tube's long narrow slot 62B, thus effecting the "armed" position of Fig. 16. When that has been done the compressive force of hammer spring 69 is transferred to the trigger sear 84, and withdrawal thereof from the latch head 83 allows the hammer to fly backwardly and cause tappet 67 to impart a percussive blow to the firing pin 42.

In addition to this loader's safety, our improved weapon here disclosed also includes: (*a*) a trigger safety; and (*b*) a firing pin safety.

The trigger safety utilizes mechanism associated with the trigger 70 within the trigger handle 18. This trigger is mounted for rotation about a support point 86 (see Fig. 3A), and the lower portion of the trigger is held forwardly by a leaf spring 87. This spring urges sear 84 upwardly into engagement with the hammer's latch head 83.

The trigger handle 18 comprises two sections fastened to a carrier member 94 which is fixedly mounted on barrel 15. Also carried by the trigger handle 18 is a trigger guard 89, which completely surrounds the exposed portion of trigger 70 and requires that pulling movement be imparted to the trigger through application to this guard. A fastening ferrule 90 for this guard is borne by the carrier member 94 (see Figs. 3 and 10) slightly below the corresponding support 86 for the trigger.

The trigger safety feature is dependent on this guard 89 and utilizes the mechanism illustrated by Fig. 10. There the trigger guard 89 is shown as having two sides which pivot around ferrule 90. This ferrule is hollow and protruding from one end thereof is a safety button 91. This safety button terminates in a locking key 92 and is held in the extended position represented by a trigger safety spring 93 supported in compression by a hollow screw 95.

As shown in Fig. 10, this locking key 92 fits into mating slots in one side of the trigger guard 89 and is prevented from rotational motion by fitting into the slots in the stationary central plate 94 of the trigger handle. As long as the safety button 91 protrudes from the side of handle 18, as shown in Fig. 10, spring 93 holds half of this non-rotating locking key 92 in the slots in the guard side 89. Under this condition the guard is locked against rearward movement into contact with trigger 70, and application of pressure to the guard 89 is prevented from effecting trigger operation.

When, however, the safety button 91 is depressed the locking key 92 is moved completely within the handle plate 94 (see Fig. 10) and out of engagement with the trigger guard 89. Under this condition the guard is freed for backward movement and application of pressure thereto then becomes effective for pulling the trigger and firing the weapon. In view of the fact that the safety spring 93 is continuously acting as aforesaid to move the safety button 91 into the "safe" position, the button must be kept depressed by the gunner during the entire time it is desired to keep trigger guard 89 free for actuation of the trigger.

The third or "firing pin" form of safety involves the hammer tappet 67 and engagement of the inner end thereof with the firing pin 42 carried by the weapon's breech block 17. Surrounding the end of this firing pin (see Figs. 3 and 8) is the rearward boss 58, earlier described as fitting into a mating opening in the inner end of the tappet housing 50.

In order that the tappet 67 may strike the firing pin, this circular boss 58 is provided with the slot 65 best represented in Fig. 8. When properly aligned with the tappet this slot permits such forward movement thereof as is necessary to impart a detonating blow to the firing pin.

This proper alignment (see Fig. 7) exists only when the breech block 17 is locked within chamber 16 by clockwise rotation of lugs 29 behind the chamber's mating protrusions 30. When the breech block's lugs are disengaged from the chamber, this breech boss 58 is rotated to a position where the described slot therein no longer aligns with the tappet, and under this condition the boss wall mechanically blocks advancement of the tappet into contact with the firing pin.

Hence, even though the breech block 17 may be inserted into the chamber it is possible to fire the weapon only after there has been imparted to that block sufficient clockwise rotation to effect secure locking in the firing position.

Other mechanical details

For facilitating assembly and disassembly of the just described firing mechanism and other parts of our recoilless weapon, we have provided a multi-purpose gun tool of the unique character which Figs. 18–19 show.

This tool consists of a metal shank or body 96 which: (*a*) has a turning handle formed of two metal rods that terminate in hexagonal "wrench" ends 97—98; (*b*) extends into a small diameter screw driver 99 backed by a shoulder from which slot-engaging wings 100 protrude; and (*c*) carries a knurled disc 101 so pivoted off-center as to

wedge a member to be turned into a cooperating recess 102 in the tool's body.

By this one tool the following five operations can be performed: (*a*) the gun's breech cap bolts 61 (see Figs. 4 and 7) can be turned by inserting wrench end 97 into the mating recesses in the bolt heads; (*b*) the gun's orifice block bolts 64 (see Figs. 5 and 7) can be turned by similarly inserting wrench end 98 into corresponding bolt head recesses; (*c*) the gun's trigger handle screw 95 (see Fig. 10) can be turned by engaging screw driver blade 99 with the slotted head thereof; (*d*) the gun's hinge housing plug 78 (see Fig. 3A) can be turned by a "wedge" engagement thereof between knurled disc 101 and the opposing side of the tool's recess 102; and (*e*) the gun's spring retainer 76 (see Fig. 3A) can (after removal of plug 78 and withdrawal of hammer 68) be turned by inserting the tool's small diameter end 99 into the retainer's center and bringing wing extensions 100 into engagement with cooperating slots (not shown) in the retainer's end face.

The smallness and lightness of this multipurpose tool allows it readily to be carried by the gun operator for immediate availability at all times.

Loading and firing

From the foregoing it will be seen that we have provided an improved recoilless firearm which offers special advantages in connection with both loading and firing. To place the ammunition round within the weapon it is merely necessary to unlock the breech block 17, withdraw it from chamber 16 and swing it downwardly to the position shown in Fig. 5, thus completely freeing the chamber opening.

The ammunition round is now inserted into the opened chamber and the rear of the barrel's bore. As the projectile enters the barrel, the lands on the pre-engraved band 46 are brought into alignment with the grooves of the barrel bore, and forward thrust is then continued until the shoulder ring 44 at the cartridge case front abuts with the barrel's end. In this position the projectile 32 imparts centering support to the entire cartridge case 33 and allows the rear head 41 thereof to droop only slightly from the rear chamber center.

The breech block 17 is now moved forwardly into the chamber. In approaching and engaging with the cartridge case head 41, the flared recess in the breech block's front serves to center the head thereby constituting a second support for the cartridge case. Clockwise rotation of the breech block by handles 49 now locks it into the chamber with the front shoulder ring in abutment with the barrel and the case head 41 in abutment with the breech block, the primer 35 in alignment with the firing pin 42 and the entire cartridge case 33 centrally positioned within the surrounding chamber 16.

The weapon is now ready for firing, and upon the earlier explained presetting of safety arm 81 and depression of trigger button 91, a backward pressure on trigger guard 89 will cause detonation of primer 35 and ignition of booster and propellent charges 37 and 34.

The resultant combustion of propellent 34 discharges the projectile 32 and at the same time ruptures the frangible layer 39 and produces radial expulsion of the explosive gases into the chamber 16. This expulsion starts early in the burning cycle and is accompanied by continued combustion of the powder.

The resultant pressure within the chamber produces escape of explosive gas through the annular breech venturi and thence to the rear of the weapon. In a manner already explained in part and to be further analyzed presently, this escape of explosive gas sets up counterforces which neutralize recoil and thus permit the weapon to be fired either from the shoulder, as shown in Fig. 1, or from a light tripod of the character represented in Fig. 2.

The perforated wall metal of the cartridge case 33 remains intact during this firing and is not ruptured or otherwise damaged. Indications are that the pressure within the chamber 16 on the inside and outside of the cartridge case wall equalizes itself early during the burning cycle. Thus, after the case has been fired some of the openings 38 may be found to have thin films of ash either partially or completely covering their area.

Subsequent withdrawal of the fired cartridge case from the chamber is effected by unlocking the breech block, withdrawing it rearwardly and swinging it downwardly out of register with the chamber. This frees the fired case for ready withdrawal from the chamber and conditions the weapon for insertion and subsequent firing of another ammunition round.

Performance data

The firing of hundreds of rounds of ammunition has confirmed beyond all doubt the successful and practical character of the improved recoilless firearm here disclosed. For example, in tests where the represented projectile 32 which was used has a weight of between 2.5 and 3 pounds, by use of the proper propellent charge muzzle velocities in excess of 1200 feet per second were consistently attained.

Complete neutralization of recoil is uniformly achieved, and when firing the weapon from the shoulder users report a complete absence of weapon motion backward, rotative, sidewise or forward. The same, of course, holds true when the weapon is fired from a tripod as shown in Fig. 2.

Accuracies of a high order also are achieved. At 300 yards it is possible to hit a one-foot bull's-eye with remarkable consistence; at 600 yards the shot pattern area is well defined by a 3-foot circle; and at 1000 yards hits can be scored on a 6-foot target. Accuracies of comparable order are realized at 1500 and 2000 yards, and high effectiveness of the weapon is found to continue even up to 3000 yards.

The relatively light weight and small dimensions of the weapon at once make it possible for infantry use and place in the hands of the individual soldier an effective defense and offense against enemy tanks and other military objectives. The disclosed novel construction, moreover, assures maximum burning of the powder within the chamber, minimum discharge of unburned powder to the rear, maximum utilization of the propellent's explosive energy in speeding the projectile out of the barrel, minimum apportionment of the total propellent charge energy to the recoil neutralizing rear blast, and marked reduction in the danger area behind the gun.

Interior ballistic theory of recoilless firearms

In a conventional closed-breech gun, the pressure-travel characteristic rises to a high peak after a relatively short projectile travel; it then falls rapidly after powder combustion is completed; due to the rapid expansion and cooling of the gases as they continue to drive the projectile through the bore. This is a very efficient

process and results in the conversion of as high as 30% of the internal energy of the powder gas to projectile kinetic energy.

In an open-breech recoilless gun the pressure, after burning has ended, falls not only due to the forward motion of the projectile but also because of the very considerable amount of gas issuing from the breech. It turns out, therefore, that a recoilless gun, projectile and powder charge combination designed for completion of powder combustion at the moment of projectile exit from the muzzle is only slightly less efficient than the same combination with an equal charge of a faster powder which would operate at a higher pressure and which would give some expansion of the gases after burning ends.

For in the latter case, although a higher pressure peak is obtained and the powder combustion is completed earlier, just as in the conventional gun, much of the benefit of the consequent gas expansion behind the moving projectile is lost. This is because the nozzle discharge becomes more effective as the gas temperature falls, and the driving pressure thus is lowered more rapidly than would be the case during the corresponding gas expansion in a conventional gun.

In our analysis of the physical mechanism of the recoilless gun and its application to design, we consequently have concentrated upon the objective of obtaining the best possible gun powder combustion completed at the instant of projectile exit from the muzzle. This results in a pressure-travel characteristic which, when graphically illustrated, has an essentially flat shape and offering what we have found to be the best solution of the weight problem.

Summary

The earlier described qualities of superior recoilless gun performance are the direct result of our here disclosed inventive improvements in the design and construction of open-breech firearms. The individual features of such improvement are numerous, and in the complete weapon these features effect the named results through cooperation and interaction which are both unique and novel.

Our disclosed arrangement and correlation of recoilless firearm components is not believed to have been either suggested or used heretofore, and although we are aware that certain of the individual elements of our improved weapon may have existed in other environments, yet it has remained for us to perceive their advantageous interacting possibilities and to correlate them in a wholly new and unexpected manner which yields the superior performance results already set forth.

From the foregoing it will thus be seen that we have improved the design and extended the usefulness of non-recoil guns wherein the forces of rearward reaction that results from projectile discharge are neutralized by forwardly acting counterforces simultaneously set up by release of powder gases through an orifice in the gun's breech; that we have lightened the weight and increased the fire power of recoilless weapons of the named open-breech type; that we have evolved for such firearms a quantitative theory of ballistic design plus empirical formula of proven accuracy; that we have provided improved chamber and breech constructions for such recoilless guns and have made available new and improved ammunition for use therein; that we have facilitated the construction and adjustment of breech orifice nozzle and have more efficiently secured zero recoil at a desired performance level; that we have assured substantially complete combustion of the powder within the gun's chamber and thereby minimized the blast to the rear and accompanying discharge of unburned powder and fragments; and that we have made possible the construction of a practical one-man recoilless firearm capable of shooting projectiles of substantial size through relatively long distances and yet not exceeding the weight limitations of an infantry weapon.

Our inventive improvements thus are capable of wide application and hence are not to be restricted to the specific form here shown and described by way of illustration.

We claim:

1. In a recoilless firearm, the combination of a barrel, a chamber communicating therewith, an ammnuition round comprising a projectile positioned in the rear bore of said barrel and a cartridge case within said chamber communicating with said projectile and containing propellent powder, a metal wall for said case forming for said powder a cylindrical enclosure of diameter substantially less than that of the surrounding chamber so as to leave sufficient space between said case wall and surrounding chamber for radial expansion of powder combustion gases through selected wall area portions which constitute a substantial percentage of the total case wall area, a breech block secured in the rear of said chamber and there providing an orifice which leads from the chamber's interior to the rear exterior thereof and which permits escape of powder gases in proper quantity and at proper rate to neutralize recoil, and means including said breech block for supporting said cartridge case in spaced relation to the chamber wall therearound.

2. In a recoilless firearm, the combination of a barrel, a chamber communicating therewith, an ammunition round comprising a projectile positioned in the rear bore of said barrel and a cartridge case containing propellent powder positioned within said chamber and communicating with said projectile, a metal wall for said case forming for said powder a cylindrical enclosure of diameter substantially less than that of the surrounding chamber and being perforated by a relatively large number of openings distributed throughout the circumference and length thereof, a breech block so constructed and so mounted in the rear of said chamber as to support said cartridge case in spaced relation to the chamber walls and further so as to provide an orifice which leads from the chamber's interior to the rear exterior thereof, means for igniting said powder whereby to discharge said projectile forwardly out of said barrel and at the same time expel through said case wall openings radially into said chamber and thence rearwardly out of said orifice powder combustion gases which neutralize the forces of recoil.

3. In a recoilless firearm, the combination of a barrel, a chamber communicating therewith, an ammunition round comprising a projectile positioned in the rear bore of said barrel and a cartridge case containing propellent powder positioned within said chamber and communicating with said projectile, a metal wall for said case forming for said powder a cylindrical enclosure of diameter substantially less than that of the surrounding chamber and being perforated by a relatively large number of openings distributed throughout the circumference and length there-

of to permit radial gas expansion upon combustion of the powder, and a breech block in the rear of said chamber there supporting said cartridge case in spaced relation to the chamber walls and there also providing an orifice which leads from the chamber's interior to the rear exterior thereof and which permits escape of powder gases in proper quantity and at proper rate to neutralize recoil.

4. In a recoilless firearm, the combination of a barrel, a chamber communicating therewith, an ammunition round comprising a projectile positioned in the rear bore of said barrel and a cartridge case positioned within said chamber communicating with said projectile and containing propellent powder, a metal wall for said case forming for said powder a cylindrical enclosure of diameter substantially less than that of the surrounding chamber and being perforated by a relatively large number of openings distributed throughout the circumference and length thereof, a layer of frangible material separating said powder from and preventing its passage through the case wall perforations prior to firing but yielding to the gas pressure of powder combustion, a breech block secured in the rear of said chamber and there providing an orifice which leads from the chamber's interior to the rear exterior thereof and which permits escape of powder gases in proper quantity and at proper rate to neutralize recoil, and means including said breech block for supporting said cartridge case in spaced relation to the chamber wall therearound.

5. In a non-recoil gun, the combination of a barrel, a chamber communicating therewith, an ammunition round comprising a projectile positioned in the rear bore of said barrel and a cylindrical cartridge case having a perforated metal wall positioned within said chamber communicating with said projectile and having a diameter substantially less than that of said chamber, propellent powder within said cartridge case, a breech block secured in the rear of said chamber in radially spaced relation to the chamber wall and there forming with that wall a substantially annular orifice leading from the chamber's interior to the rear exterior thereof, and means including said breech block for supporting said perforated cartridge case in spaced relation to the chamber wall therearound.

6. In a non-recoil gun, the combination of a barrel, a chamber communicating therewith, an ammunition round comprising a projectile positioned in the rear bore of said barrel and a cylindrical cartridge case having a perforated metal wall within said chamber communicating with said projectile and having a diameter substantially less than that of said chamber, propellent powder within said cartridge case, a breech block secured in the rear of said chamber and there providing a rearwardly diverging orifice which leads from the chamber's interior to the rear exterior thereof and which upon combustion of said powder and discharge of said projectile permits rearward escape of powder gases in proper quantity and at proper rate to neutralize recoil, and means including said breech block for supporting said perforated cartridge case in spaced relation to the chamber wall therearound.

7. In a recoilless firearm, the combination of a barrel, a chamber communicating therewith and having an internal diameter substantially greater than that of the barrel, an ammunition round comprising a projectile positioned in the rear bore of said barrel and a cartridge case containing propellent powder positioned within said chamber and communicating with said projectile, a metal wall for said case forming for said powder a cylindrical enclosure of diameter substantially less than that of the surrounding chamber so as to leave sufficient space between said case wall and said surrounding chamber for radial expansion of powder combustion gases through selected wall area portions which constitute a substantial percentage of the total case wall area, and a breech block in the rear of said chamber there supporting said cartridge case in spaced relation to the chamber walls and there also providing an orifice which leads from the chamber's interior to the rear exterior thereof and which permits escape of powder gases in proper quantity and at proper rate to neutralize recoil.

8. In a non-recoil gun, the combination of a barrel having a rifled bore, a chamber communicating with said barrel, an ammunition round comprising a projectile positioned in the rear of said bore having a rotating band pre-engraved to match the bore's rifling and being dimensioned for free forward movement through the barrel and a cartridge case containing propellent powder positioned within said chamber and communicating with said projectile, a metal wall for said case forming for said powder a cylindrical enclosure of diameter substantially less than that of the surrounding chamber so as to leave sufficient space between said case wall and said surrounding chamber for radial expansion of powder combustion gases through selected wall area portions, and a breech block in the rear of said chamber there supporting said cartridge case in spaced relation to the chamber walls and there also providing an orifice which leads from the chamber's interior to the rear exterior thereof and which permits escape of powder combustion gases in proper quantity and at proper rate to neutralize recoil.

9. In a recoilless firearm, the combination of a barrel having a rifled bore, a chamber communicating with said barrel, an ammunition round comprising a projectile positioned in the rear of said bore having a rotating band pre-engraved to match the bore's rifling and being dimensioned for free forward movement through the barrel and a cartridge case containing propellent powder positioned within said chamber and communicating with said projectile, a metal wall for said case forming for said powder a cylindrical enclosure of diameter substantially less than that of the surrounding chamber and being perforated by a relatively large number of openings distributed throughout the circumference and length thereof, a breech block in the rear of said chamber there supporting said cartridge case in spaced relation to the chamber walls and there also providing an orifice which leads from the chamber's interior to the rear exterior thereof, and means for igniting said powder whereby to discharge said projectile forwardly out of said rifled barrel and at the same time expel through said case wall perforations radially into said chamber and thence rearwardly out of said breech orifice powder combustion gases which neutralize the forces of recoil.

10. In a non-recoil gun, the combination of a barrel having a bore rifled with twist in a given direction, a chamber secured to the rear of said barrel having the periphery of its internal wall surface cut away at spaced portions to provide a substantially annular orifice interrupted by locking protrusions that extend substantially radially

inward from the chamber's inner wall toward its central cavity, an ammunition round comprising a projectile positioned in said barrel's rear bore and a cartridge case containing a propellent charge for generating combustion gases by which said projectile is pushed forwardly through said barrel and rotated in said given direction by said bore's rifling, a metal wall for said case forming for said charge a cylindrical enclosure of diameter substantially less than that of the surrounding chamber and being perforated by a relatively large number of openings distributed throughout the circumference and length thereof, a breech block in the rearward portion of said chamber having its periphery cut away at spaced portions circumferentially of the block to provide a substantially annular orifice interrupted by vanes that extend substantially radially from the block's central portion and that cooperate with said locking protrusions within said chamber to secure the breech block within the chamber, and means including said vanes for causing the said combustion gases which pass rearwardly through said annular orifice to impart to said breech block and chamber given-direction rotative forces substantially equal to the forces of twist which said projectile receives from said rifled barrel.

11. In a non-recoil gun, the combination of a barrel having a bore rifled with twist in a given direction, a chamber secured to the rear of said barrel having the periphery of its internal wall surface cut away at spaced portions to provide a substantially annular orifice interrupted by locking protrusions that extend substantially radially inward from the chamber's inner wall toward its central cavity, an ammunition round comprising a projectile positioned in said barrel's rear bore, a propellent charge for generating combustion gases by which said projectile is pushed forwardly through said barrel and rotated in said given direction by said bore's rifling, a metal wall for said case forming for said charge a cylindrical enclosure of diameter substantially less than that of the surrounding chamber and being perforated by a relatively large number of openings distributed throughout the circumference and length thereof, a breech block in the rearward portion of said chamber having its periphery cut away at spaced portions circumferentially of the block to provide a substantially annular orifice interrupted by vanes that extend substantially radially from the block's central portion and that cooperate with said locking protrusions within said chamber to secure the block within the chamber, and side walls for said vanes so flared axially as to receive from the said combustion gases which pass rearwardly through said annular orifice given-direction rotative forces substantially equal to the forces of twist which said projectile receives from said rifled barrel.

12. In a non-recoil gun, the combination of a barrel having a bore rifled with twist in a given direction, a chamber secured to the rear of said barrel having the periphery of its internal wall surface cut away at spaced portions to provide a substantially annular orifice interrupted by locking protrusions that extend substantially radially inward from the chamber's inner wall toward its central cavity, an ammunition round comprising a projectile positioned in said barrel's rear bore and a cartridge case containing a propellent charge for generating combustion gases by which said projectile is pushed forwardly through said barrel and rotated in said given direction by said bore's rifling, a metal wall for said case forming

for said charge a cylindrical enclosure of diameter substantially less than that of the surrounding chamber and being perforated by a relatively large number of openings distributed throughout the circumference and length thereof, a breech block in the rearward portion of said chamber having its periphery cut away at spaced portions circumferentially of the block to provide a substantially annular orifice interrupted by vanes that extend substantially radially from the block's central portion and that cooperate with said locking protrusions within said chamber to secure the block within the chamber, and rearwardly extending side walls for said vanes axially flared by unequal angles on opposing sides to receive from the said combustion gases which pass through said annular orifice given-direction rotative forces substantially equal to the forces of twist which said projectile receives from said rifled barrel.

13. In a non-recoil gun, the combination of a barrel, a chamber communicating with said barrel, a breech block movable into and out of the rearward portion of said chamber and having its periphery cut away at spaced portions circumferentially of the block to provide a substantially annular orifice interrupted by vanes extending substantially radially from the central portion of the block, and coacting interlocking members formed on the peripheral portions of said vanes and the inner wall of said chamber.

14. In a non-recoil gun, the combination of a barrel, a chamber communicating with said barrel, a breech block operable for movement into and out of the rearward portion of said chamber for locking engagement therewith and having its periphery cut away at spaced portions circumferentially of the block to provide a substantially annular orifice interrupted by vanes extending substantially radially from the central portion of the block, coacting interlocking members formed on the peripheral portions of said vanes and the inner wall of said chamber, and a breech block operating member carried by one of said vanes and usable for moving the breech block into and out of locking engagement with said chamber.

15. In a non-recoil gun, the combination of a barrel, a chamber communicating with said barrel, a breech block movable into and out of the rearward portion of said chamber and having its periphery cut away at spaced portions circumferentially of the block to provide a substantially annular orifice interrupted by vanes extending substantially radially from the central portion of the block, coacting interlocking members formed on the peripheral portions of said vanes and the inner wall of said chamber, a cartridge case of cross sectional area substantially less than that of said chamber supported adjacent its forward end in said barrel and having its side walls perforated, and means carried by the forward portion of said breech block to support the rearward portion of said cartridge case in spaced relation to the chamber wall, said substantially annular orifice connecting the annular space between the cartridge case and chamber wall with the outside atmosphere.

16. In a non-recoil gun, the combination of a barrel, a chamber communicating with said barrel, a breech block movable into and out of the rearward portion of said chamber and having its periphery cut away at spaced portions circumferentially of the block to provide a substantially annular orifice interrupted by vanes extending

substantially radially from the central portion of the block, and coacting interlocking members formed on the peripheral portions of said vanes and the inner wall of said chamber, the breech block walls of said annular orifice and the adjacent walls of said chamber diverging rearwardly to produce a rearwardly flared annular opening of nozzle shape.

17. In a non-recoil gun, the combination of a barrel, a chamber communicating with said barrel, a breech block movable into and out of the rearward portion of said chamber and having its periphery cut away at spaced portions circumferentially of the block to provide a substantially annular orifice interrupted by vanes extending substantially radially from the central portion of the block, coacting interlocking members formed on the peripheral portions of said vanes and the inner wall of said chamber, and adjustable means usable for selectively varying the effective cross sectional area of said annular orifice in order to accomplish substantial elimination of all recoil from the gun notwithstanding dimensional changes to the breech block or chamber caused by use of the gun.

18. In a non-recoil gun, the combination of a barrel, a chamber communicating with said barrel, a breech block movable into and out of the rearward portion of said chamber and having its periphery cut away at spaced portions circumferentially of the block to provide a substantially annular orifice interrupted by vanes extending substantially radially from the central portion of the block, and coacting interlocking members formed on the peripheral portions of said vanes and the inner wall of said chamber, the block walls of said annular orifice and the adjacent walls of said chamber diverging rearwardly to produce a rearwardly flared annular opening of nozzle shape, and adjustable means selectively usable to maintain uniform the effective cross sectional area of said rearwardly diverging orifice without altering the nozzle shape thereof notwithstanding dimensional changes to the breech block or chamber caused by use of the gun.

19. In a non-recoil gun, the combination of a barrel, a chamber communicating with said barrel, a breech block movable into and out of the rearward portion of said chamber and having its periphery cut away at spaced portions circumferentially of the block to provide a substantially annual orifice interrupted by vanes extending substantially radially from the central portion of the block, coacting interlocking members formed on the peripheral portions of said vanes and the inner wall of said chamber, and an orifice area adjusting member of preselected cross section affixed to said breech block in one of said circumferentially cut away portions thereof whereby to reduce the total orifice area by the amount of said preselected cross section.

20. In a non-recoil gun, the combination of a barrel, a chamber communicating with said barrel, a breech block movable into and out of said chamber and having its periphery cut away at spaced portions circumferentially of the block to provide a substantially annular orifice interrupted by vanes extending substantially radially from the central portion of the block, coacting interlocking members formed on the peripheral portions of said vanes and the inner wall of said chamber and being engageable and disengageable upon locking and unlocking rotations of the breech block within the chamber, a support for said breech block disposed exteriorly of said chamber, a companion member rotatively and slideably engaging said support for movement longitudinally of said chamber and barrel, and means extending radially and operatively connecting said breech block to the support's said companion member and disposed in line with one of said vanes in the breech block's locked position.

21. In a recoilless firearm, the combination of a barrel, a chamber communicating therewith, a breech block movable into and out of said chamber and having its periphery cut away at spaced portions circumferentially of the block to provide a substantially annular orifice interrupted by vanes extending substantially radially from the central portion of the block, a support tube secured to the outside of the chamber and extending lengthwise thereof, a pivot tube within said support tube carried thereby and free to slide and turn with respect thereto, radial means operatively connecting said breech block to said pivot tube, a firing pin in said breech block, a tappet lever carried by said radial means and extending across said annular orifice between the axis of said firing pin and the axis of said pivot tube, and a hammer disposed within the pivot tube and movable axially thereof to engage said tappet lever and operate the firing pin.

22. In a non-recoil firearm comprising a rifled barrel in conjunction with a rear breech portion having an opening for rearward passage of propellent gases, the combination of means associated with said breech portion for converting the translatory motion of said rearwardly moving gases into a rotative force which opposes the forces of twist that are imparted to the firearm upon the firing of a projectile through said rifled barrel.

23. A rifled recoilless gun comprising a breech portion having an opening for rearward passage of propellent gases and a vane structure connected with said breech portion and so positioned with respect to said opening as to convert the translatory motion of said rearwardly moving gases into a rotative force which opposes the torque exerted upon the rifled gun when a projectile is forwardly fired therefrom.

24. In a non-recoil gun comprising a rifled barrel in conjunction with a rear tubular portion having an opening for rearward passage of propellent gases, the combination of means including vanes so related to said opening that when a projectile is forwardly fired through said rifled barrel those vanes cause the accompanying rearwardly moving explosive gases to impart to the gun rotative forces substantially equal but opposite in direction to the forces of twist which the accelerating projectile exerts upon the rifled barrel.

25. In a recoilless gun having a casing provided with a pressure developing chamber and a coaxial exhaust passage leading therefrom to the rear exterior thereof, a spider-like member removably fixed within said chamber, said member having a hub portion coaxial with said chamber and a plurality of integral vanes angularly disposed relative to the axis of and extending from said hub portion toward the walls of said chamber whereby to deflect and give a circular motion to gases exhausted axially through said exhaust passage.

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No references cited.