April 27, 1965 F. V. PORTER 3,180,221

GUN PERFORATOR

Original Filed Jan. 6, 1961 2 Sheets-Sheet 1

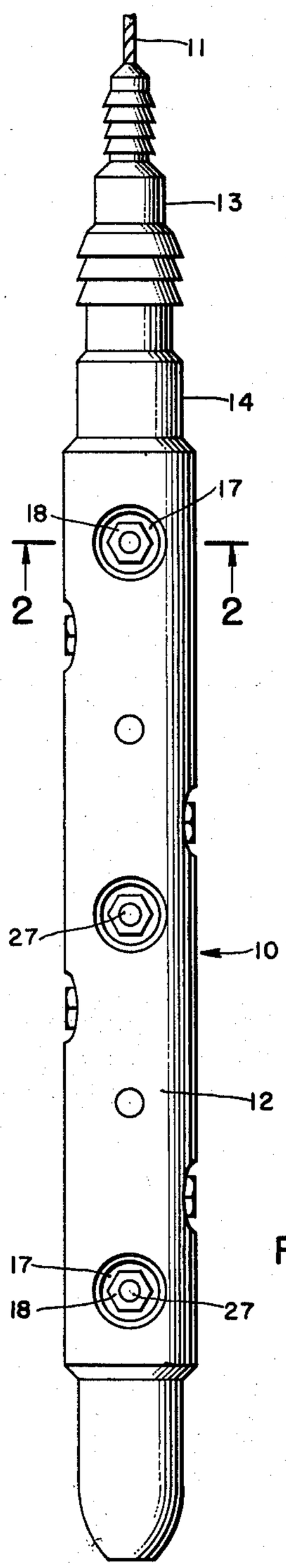

FIG. 1.

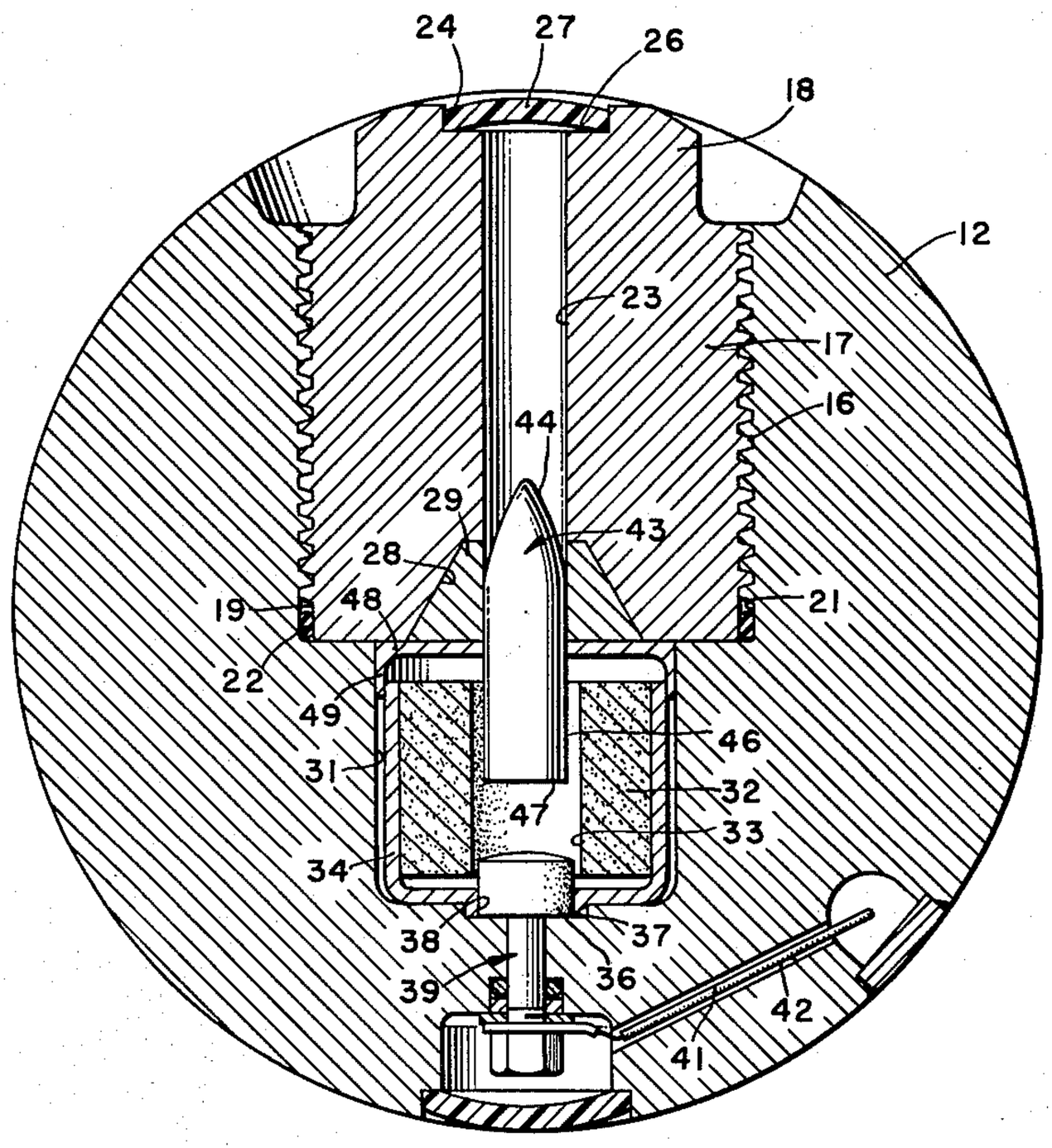

FIG. 2.

FORREST V. PORTER
INVENTOR.

BY Robert W. Mayer

ATTORNEY.

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FIG. 3.

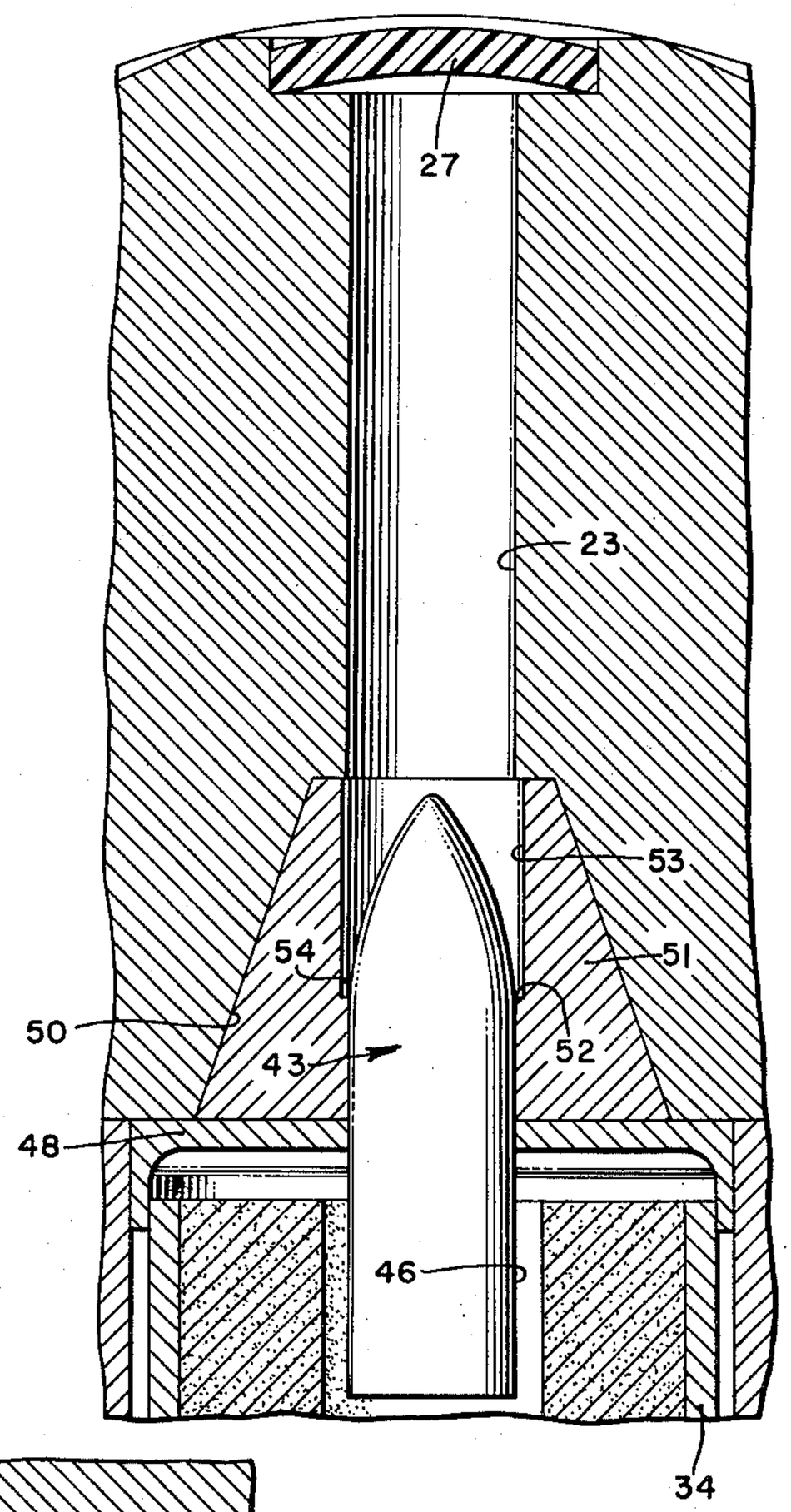
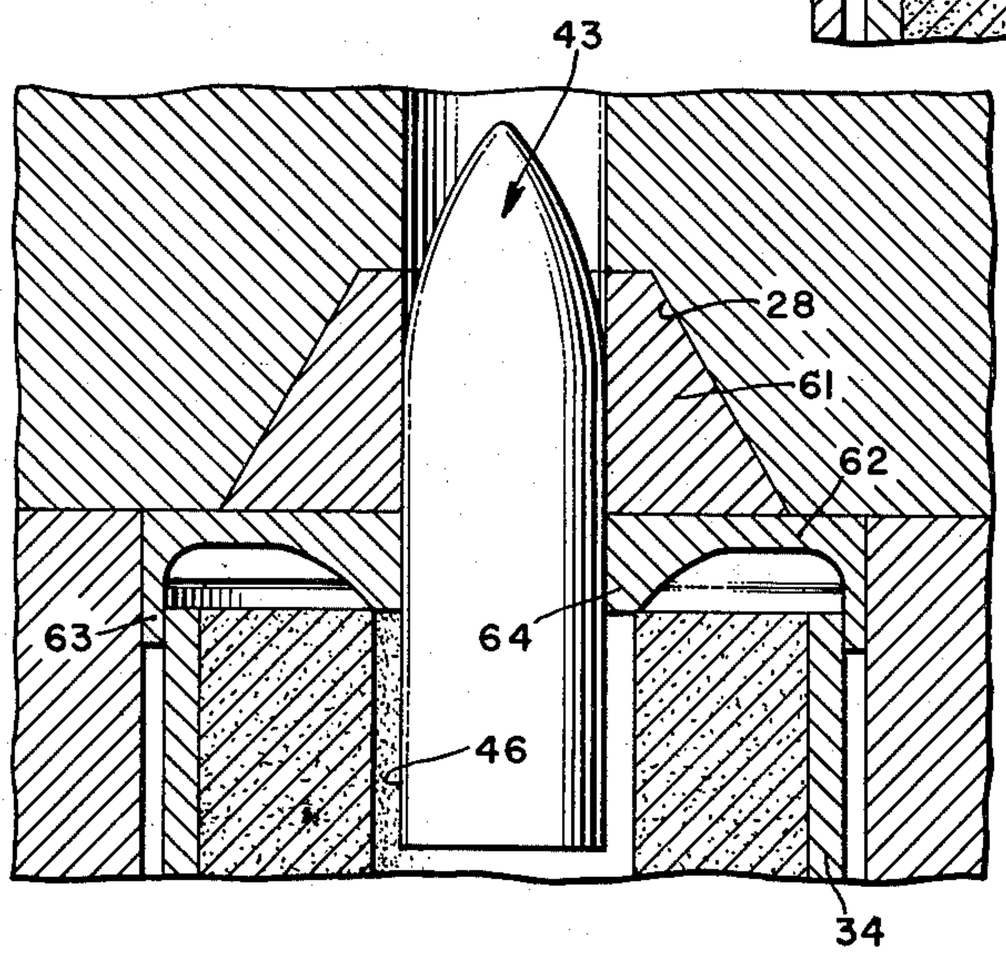


FIG. 4.



FORREST V. PORTER
INVENTOR.

BY Robert W. Mayer

ATTORNEY.

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3,180,221

GUN PERFORATOR

Forrest V. Porter, Houston, Tex., assignor to Dresser Industries, Inc., Dallas, Tex., a corporation of Delaware

Continuation of application Ser. No. 81,038, Jan. 6, 1961. This application June 19, 1963, Ser. No. 289,788

5 Claims. (Cl. 89—1)

This invention relates to bullet guns of the type used in perforating earth well casing and the formations traversed by well bores in order to permit flow of fluids into the well and, more particularly, to a gun including means for protecting the barrel from erosion and damage by propellent gases thereby increasing the useful life of this part while at the same time providing for controlled restraint of the bullet and substantially improving the ballistic efficiency of the gun. This application is a continuation of copending application for Letters Patent by Forrest V. Porter for Gun Perforator, having Serial No. 81,038, filed January 6, 1961, now abandoned.

The conventional bullet perforating gun usually includes an elongated, generally cylindrical, body portion having a plurality of internally threaded, longitudinally extending openings into which externally threaded barrel members are fitted. The barrel members are readily removable from the gun body to facilitate reloading and to permit their frequent replacement. Such replacement has been found necessary because of the erosive effect of the propellent gases resulting from ignition of the explosive charge located in the gun body adjacent the rear end of the barrel member. These propellent gases expand rapidly as a high velocity jet, which impinges against the metal around the bore of the barrel at the rear end thereof, erodes some of the metal away and gradually enlarges the diameter of the bore after the same barrel has been used for several shots.

The aforesaid bore enlargement permits expanding propellent gases to leak through the annular space between the bore and the bullet. The energy of expansion of such leaking gas is wasted, the velocity of the bullet at the time of impact with the casing is lowered and its depth of penetration correspondingly reduced. Effectiveness of the gun thus falls off with repeated use. This requires frequent replacement of barrel members which is an expensive proposition adding substantially to the cost of providing effective perforating service.

Increased utilization of the energy supplied by the propellent gases has been sought by providing restraining means for the bullet. The restraining means is often in the form of an annular member which fits tightly around the bullet and provides enough friction to hold the bullet in place until the propellent gases build up to their maximum pressure. Since the ballistic efficiency of a bullet perforator is improved by lengthening the period during which leakage of propellent gases around the bullet is prevented, it follows that it would be desirable to position the restraining means as near the front of the cylindrical portion of the bullet as possible. This is not practical in gun perforators previously available because of space limitations imposed by the fact that the gun body within which the bullet, propellent charge, barrel, etc., must fit, must be of relatively small diameter to fit within well casing.

An object of this invention is to provide a bullet perforator of improved ballistic efficiency and perforating power which is also capable of repetitive, effective and economical use.

Another object is to provide effective, practical and economical means for minimizing the leakage of propellent gases around the projectile of a well perforating gun.

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Another, more specific, object is to provide a bullet perforator of such design that the barrel portion thereof has a substantially increased effective life and requires much less frequent replacement than do the barrel members of conventional gun perforators.

Still a further object of the invention is to provide novel bullet restraining means providing an accurately controlled amount of restraining force and at the same time functioning to protect the barrel member from erosion and providing for improved sealing of propellent gases to increase their effectiveness.

The foregoing objects, as well as others, which will be in part pointed out and in part apparent from the ensuing description, are attained by the provision, in a bullet perforating gun having a plurality of laterally extending openings in the body thereof with a generally tubular barrel member secured within such openings, of an enlarged portion of frusto-conical shape at the rear end of the bore. An expendable restraining means in the form of a frusto-conical metal annulus is removably fitted within this enlarged portion and grips a bullet made of a metal harder than itself.

The shape and size of the annulus provide controlled restraint of the bullet to improve ballistic efficiency. The restraining means also serves to protect the barrel member against the erosive effect of the propellent gases during that part of the expansion cycle in which their velocity is highest and hence their deteriorating effect is greatest thus permitting the barrel member to be used effectively for many more shots than corresponding member of conventional bullet guns and maintaining uniform performance during the life of the barrel member. The restraining means is inexpensive and is replaced after each shot.

In certain embodiments of the invention the central bore of the restraining member is relieved or enlarged slightly near its front portion. This provides room by metal displaced from the rear part of the restraining member by the initial forward movement of the bullet. This arrangement permits improved control of the bullet restraining force, improves the gas sealing action of the restraining member and protects a greater length of the barrel member.

In the accompanying drawings:

FIG. 1 is a view in elevation of a typical well perforating gun embodying the features of the present invention;

FIG. 2 is a view partly in section taken on the line 2—2 of FIG. 1;

FIG. 3 is an enlarged fragmentary view partly in section of a portion of the gun illustrating a different embodiment of the invention than that shown in FIG. 2; and

FIG. 4 is a view, similar to FIG. 3 illustrating still another embodiment of the invention.

In the accompanying drawings, the reference character 10 designates the gun assembly generally and the reference character 12, the gun body. The gun comprises a steel cylindrical assembly which is adapted to be lowered into a well borehole by a conductor cable 11 containing an insulated conductor or conductors through which the firing of the gun units may be controlled. As indicated in FIG. 1, between the conductor cable 11 and the body 12 of the gun, there are provided a cable socket 13 and various interconnecting subs, one of which is shown at 14. The sub 14 contains suitable firing control means of conventional design which are not shown or described herein.

The gun body 12 comprises a generally elongated, substantially solid steel cylinder of sufficient strength and solidity to withstand the explosive forces of the firing of the gun charges. Laterally directed gun uits are mounted in the cylindrical gun body at longitudinally spaced intervals and preferably in a spiral arrangement. As illus-

trated in FIG. 2, each unit comprises an internally threaded, laterally directed barrel opening 16 which receives the externally threaded barrel member 17. In the form of barrel member here illustrated, the front or outer end portion 18 is reduced in external diameter and given a hexagonal shape in order to receive a suitable tool or wrench for its installation or removal. Preferably, the lateral depth of the barrel opening 16 and the length of the barrel member 17 are such that the barrel member is wholly received within the opening, flush with the surface of the gun body, when fully seated and tightened therein, so as not to present any laterally projecting parts when the gun is fully assembled in the manner shown in FIGS. 1 and 2.

The rear or inner end of the barrel member 17 is formed with a smooth, thread-free end 19 of slightly reduced external diameter adapted to be received concentrically within an inner, thread-free, counterbored end recess 21 of the barrel opening 16. This provides a short annular end recess between the surfaces 19 and 21 containing resilient ring 22 in order to seal the barrel member within the barrel opening and to preclude leaking of any well fluid inwardly from between the threaded portion of the barrel opening 16 and the external surface of the barrel member 17.

The barrel member 17 is formed with a concentric barrel bore 23 having at the front or muzzle end thereof a short portion of slightly enlarged diameter forming a shallow recess 24 having an annular shoulder 26. Seated within the recess 24 and making sealing engagement against the shoulder 26, there is provided a sealing disc 27 for preventing admission of well fluid into the barrel bore. The disc 27 may be seated and sealed in any suitable manner well known in the art and may be formed of any suitable material, such as brass or steel. In operation, when the propellent charge is ignited and the bullet fired, the seal 27 is ejected from the recess 24 either as a unit or in fragments and forms substantially no obstacle to the discharge of the bullet.

Barrel bore 23 is formed with a frusto-conical enlarged end portion 28 at the inner end thereof. A correspondingly shaped frusto-conical restraining annulus 29 fits within the end portion 28. A cylindrical socket 31, formed in the gun body at the rear of the barrel opening 16, accommodates an explosive charge which comprises a compressed, molded or otherwise consolidated or pelletized tubular shaped body of combustible propellant 32 formed with an opening 33 extending centrally therethrough from end to end. The propellant body 32 is surrounded and contained within a container sleeve or shell 34 which may be composed of any suitable material, preferably non-metallic, such as, for example, a paper or cloth-base, phenolic-impregnated tubing.

Igniter head 36 fits within the reduced diameter rear portion 37 of socket 31 and opening 38 in shell 34 and is positioned in close proximity to propellant 32. Igniter head 36 forms a part of a conventional igniter 39 of the type well known in the art and may, for example, be of the type shown and described in U.S. Patent 2,649,736 to R. A. Phillips. Igniter 39 is actuated electrically through conductor 41 positioned within the passage 42 and electrically connected to firing control apparatus within sub 14, which is in turn connected through the conductors of cable 11 to suitable equipment at the top of the borehole.

A bullet 43 preferably comprises a forward piercing nose portion 44 of substantially conical or ogival form and a body or rearward shank portion 46, preferably of uniform diameter extending from the nose portion 44 to a transverse rear end or butt 47. The bullet 43 is usually made of hardened steel or is steel jacketed in a manner well known in the industry to provide adequate casing and formation piercing ability. While a bullet of the shape here shown is now believed preferable in the present combination, it will be understood that the invention is not limited to this specific design of bullet. Various types of

nose shapes may be resorted to as desired in accordance with the dictates of the particular perforation operation to be performed.

The bullet 43 is mounted through the annulus 29 which forms a tight, press fit therewith near the forward end of shank portion 46. The bullet 43 also makes a tight, press fit within central opening formed in the cartridge cover 48 which is provided with a peripheral flange 49 fitting around the forward open end of shell 34. Although cover 48 is shown in FIGS. 2 and 3 as being separate from annulus 29, it may be integral therewith and in some instances it has been found preferable to form the cover 48 and the annulus 29 as a single piece. The fit of bullet 46 within restraining annulus 29 is sufficiently tight to form a substantially gas-tight seal.

Restraining annulus 29 is preferably made of a hard heat-treated steel so that it will be capable of providing a strong gripping force on bullet 43. However, it is made of material softer than bullet 43 as will be discussed subsequently.

In operation of the gun, igniter 39 is actuated by electric current supplied through conductor 41 and ignites propellant 32 forming a body of hot propellent gases within socket 31. The pressure of these gases builds up against the butt 47 of bullet 43 until it is sufficient to overcome the restraining force of the restraining annulus 29. At this point, the bullet 43 begins to move toward the forward end of bore 23. The tight fit between restraining annulus 29 and shank 46 of bullet 43 prevents any substantial leakage of propellent gases around the bullet. Thus, a maximum amount of the expanding pressure of the propellent gases is utilized to accelerate bullet 43 and provide it with increased penetrating force. In addition, the rear end of barrel bore 23 is shielded from the erosive effect of the high velocity propellent gases which sweep along the surface of annulus 29. By the time the butt 47 of bullet 46 has passed the front end of annulus 29, the rate of expansion of the propellent gases has slowed down considerably and their erosive power, due to their velocity, has been correspondingly reduced. In any case, enlargement of barrel bore 23 towards its midportion has relatively little effect on gun performance because bullet 46 has already been accelerated to nearly its maximum velocity when it enters this portion of the barrel bore 23. Gas leakage around the bullet 46 is of less effect than while it is receiving its initial acceleration.

For certain perforator applications it has been found desirable to further improve the seal between the bullet and the propellent gases. This is accomplished by providing the embodiment of the present invention shown in FIG. 3. In this embodiment, barrel bore 23 has an enlarged inner end portion 50 somewhat longer than corresponding portion 28 of the embodiment shown in FIG. 2. The shank 46 of bullet 43 makes a press fit inside the annular restraining means 51 which is similar to the annular restraining means 29 illustrated in FIG. 2 except that it is longer in the sense that it extends further toward the front of barrel member 17 and that it is formed with an internal shoulder 52 and an internal relieved portion 53. It is to be understood that FIG. 3 is greatly exaggerated for purposes of clarity and that the width of shoulder 52 is only about 0.002 to 0.003 inch. The internal diameter of the restraining means 51 actually gripping shank 46 is approximately the same as that of the barrel bore 23 or slightly smaller. Restraining annulus 51 is made of hard heat-treated steel but is softer than bullet 43.

When bullet 43 begins to move toward the front of barrel bore 23 under the influence of the expanding propellent gas, it displaces metal from the shoulder portion 52 and carries it into the space designated by reference character 54. This "peeling" action serves to maintain a gas-tight seal around bullet 43 while its shank 46 passes through the entire length of annulus 51.

There are a number of advantages to use of an annular restraining member of the type illustrated in FIG. 3. Because it extends further toward the front of the barrel bore 23 it affords increased protection to this member from the erosive effect of the expanding propellent gases. Also, since the period during which the bullet 43 is in a tight gas sealing relation to the restraining member 51 is increased, the ballistic efficiency of the gun is improved.

In the embodiments illustrated in FIGS. 2 and 3, the bullet 43 is made of metal harder than the restraining member 29 or 51. For example, the bullet usually has a Rockwell "C" Hardness of from about 61 to about 65 whereas the restraining member usually has a hardness in the range of about 32 to about 35, measured on the same scale.

FIG. 4 illustrates an embodiment of the invention wherein an annular insert at the rear of the barrel bore serves to protect that member from erosion while restraint on the bullet is partially or wholly supplied by the cartridge cover as deformed by expansion of propellent gases. The general organization of this embodiment is similar to that illustrated in FIG. 2 with an annular member 61 similar in shape to annulus 29 positioned within the enlarged frusto-conical end 28 of the barrel bore 23. In the embodiment illustrated in FIG. 4, however, the annulus 61 while engaging shank 46 of bullet 43 grips it less tightly than in a press fit. An annular metal cover 62 having an external peripheral flange 63 engaging shell 34 and an internal flange 64 engaging the shank 46 of bullet 43 is provided in the same position as cover 48 of the FIG. 2 embodiment. Although annulus 61 and cover 62 are shown in FIG. 4 as separate members, it will be understood that they may be formed as a single integral piece.

Initially the flange 64, which is of annular configuration, fits against shank 46 of bullet 43 less tightly than in a press fit. However, on ignition of propellant 32 the tremendous pressure of the propellent gases thus generated is exerted against flange 64 tending to deform it by forcing it inwardly against the shank 46 of bullet 43. Thus, a substantially gas-tight seal is formed during the period during which such a seal is required to utilize most effectively the expansion of these gases.

Internal flange 64 is preferably made somewhat thicker than the rest of cover 62 in order that it will not be torn loose by the pressure of the propellent gases and carried thereby through barrel bore 23 into the well and possibly into the perforation formed by bullet 43.

In this embodiment of the invention, the annulus 61 functions solely as a shield to protect the rear end of the barrel member 17 against the erosive action of the expanding propellent gases in the same manner as was explained in connection with the embodiments shown in FIGS. 2 and 3.

The embodiment illustrated in FIG. 4 may be further modified for applications in which a greater amount of bullet restraint is desirable in that the annulus 61 or the flange 64 may initially make a press fit or a light press fit with shank 46 of bullet 43 with the seal thus provided being augmented by the additional sealing pressure exerted by the propellent gases against the flange 64 as described herein.

In each of these embodiments illustrated and described, the annular inserts 29, 51 or 61 are easily rmeoved from the barrel member 17 after each shot. This is because the frusto-conical shape of these inserts prevents them from being permanently jammed into the enlarged end of the bore by lateral force exerted by passage of a bullet through them. This facilitates reloading of the gun wherein a new annulus is positioned in the enlarged end of the barrel bore after each shot, either as a separate piece or as an integral part of the cartridge forming part of the bullet assembly. The expendable annular inserts are relatively inexpensive and the cost of their replacement after each shot is extremely low compared to the savings effected by the lengthening of the performance life of the barrel members. For example, the cost of a typical barrel member is about $3.90 whereas the cost of a typical insert is about $0.03.

Extensive tests of guns embodying the present invention indicate that the improved gas seal obtained thereby increases by as much as 30% the penetration previously obtained with otherwise identical tools. The shielding of the rear end of the barrel bore from the erosive effects of the expanding propellent gases has been found to increase effective barrel life by more than 300%.

It will be understood, of course, that numerous minor changes in design may be made with respect to the embodiments of the invention heretofore described without departing from the spirit thereof as expressed in the following claims:

1. In a bullet gun assembly for use in perforating a well casing or the like, said gun assembly being formed of a generally cylindrical body provided with at least one laterally extending opening forming an individual gun, the opening comprising an inner portion accommodating an explosive charge and ignition means, the explosive charge being an annular body having a central bore therethrough and an enlarged outer portion in which is removably secured a generally tubular barrel member having a central bore forming a barrel with inner and outer ends, the inner end opposing the explosive charge, a charge cover between the explosive charge and inner end of the barrel, the central bore of the barrel adapted to receive a bullet, the improvement which comprises: the inner end of the barrel bore having a frusto-conical enlarged end portion, a removable frusto-conical restraining member formed of steel positioned in the frusto-conical enlarged end portion of the barrel bore, the frusto-conical member having a central bore axially aligned with the axis of the barrel bore, a bullet having a nose and shank portion, with the forward portion of said shank portion positioned in said central bore of the frusto-conical member and forming a press fit with the inner portion of said bore to form a substantially gas-tight seal, the rearward portion of said shank portion extending into the bore of the explosive charge, said frusto-conical restraining means being effective to act as a gas seal for the rearward portion of the shank of the bullet to increase bullet velocity and protect the inner end of the barrel bore against erosion by propellent gases.

2. In a bullet gun assembly for use in perforating a well casing or the like, said gun assembly being formed of a generally cylindrical body provided with at least one laterally extending opening forming an individual gun, the opening comprising an inner portion accommodating an explosive charge and ignition means, the explosive charge being an annular body having a central bore therethrough and an enlarged outer portion in which is removably secured a generally tubular barrel member having a central bore forming a barrel with inner and outer ends, the inner end opposing the explosive charge, a charge cover between the explosive charge and inner end of the barrel, the central bore of the barrel adapted to receive a bullet, the improvement which comprises: the inner end of the barrel bore having a frusto-conical enlarged end portion, a removable frusto-conical restraining member formed of steel positioned in the frusto-conical enlarged end portion of the barrel bore, the frusto-conical member having a central bore axially aligned with the axis of the barrel bore, a bullet having a nose and shank portion, with the forward portion of said shank portion positioned in said central bore of the frusto-conical member and forming a press fit with the inner portion of said bore to form a substantially gas-tight seal, the rearward portion of said shank portion extending into the bore of the explosive charge, the material forming the frusto-conical member being softer than the material forming the bullet to prevent displacement of the material

forming the frusto-conical member upon propulsion of the bullet, said frusto-conical restraining means being effective to act as a gas seal for the rearward portion of the shank of the bullet to increase bullet velocity and protect the inner end of the barrel bore against erosion by propellent gases.

3. In a bullet gun assembly for use in perforating a well casing or the like, said gun assembly being formed of a generally cylindrical body provided with at least one laterally extending opening forming an individual gun, the opening comprising an inner portion accommodating an explosive charge and ignition means, the explosive charge being an annular body having a central bore therethrough and an enlarged outer portion in which is removably secured a generally tubular barrel member having a central bore forming a barrel with inner and outer ends, the inner end opposing the explosive charge, the central bore of the barrel adapted to receive a bullet having a nose and shank portion, the improvement which comprises: a frusto-conical-enlarged portion extending into the inner end of the shank portion of the barrel bore approximately the length of the bullet; a removable mating frusto-conical restraining member formed of steel positioned in the frusto-conical enlarged portion of the barrel bore, the frusto-conical member having a central bore axially aligned with the axis of the barrel bore, the inner portion of said central bore being approximately the same diameter as the barrel and the outer portion being of a slightly larger diameter; the forward portion of the shank portion of the bullet positioned in said central bore of the frusto-conical member and forming a press fit with the inner portion of said bore to form a substantially gas-tight seal, the rearward portion of said shank portion extending into the bore of the explosive charge, said frusto-conical restraining means being effective to act as a gas seal for the rearward portion of the shank of the bullet to increase bullet velocity and protect the inner end of the barrel bore against erosion by propellent gases.

4. In a bullet gun assembly for use in perforating a well casing or the like, said gun assembly being formed of a generally cylindrical body provided with at least one laterally extending opening forming an individual gun, the opening comprising an inner portion accommodating an explosive charge and ignition means, the explosive charge being an annular body having a central bore therethrough and an enlarged outer portion in which is removably secured a generally tubular barrel member having a central bore forming a barrel with inner and outer ends, the inner end opposing the explosive charge, a charge cover between the explosive charge and inner end of the barrel, the central bore of the barrel adapted to receive a bullet having a nose and shank portion, the improvement which comprises: a frusto-conical enlarged portion extending into the inner end of the barrel bore approximately the length of the shank portion of the bullet, a removable mating frusto-conical restraining member formed of steel positioned in the frusto-conical

enlarged portion of the barrel bore, the frusto-conical member having a central bore axially aligned with the axis of the barrel bore, the inner portion of said central bore being approximately the same diameter as the barrel and the outer portion being of a slightly larger diameter, the forward portion of said shank portion of the bullet positioned in said central bore of the frusto-conical member and forming a press fit with the inner portion of said bore to form a substantially gas-tight seal, the rearward portion of said shank portion extending into the bore of the explosive charge, the material forming the frusto-conical member being softer than the material forming the bullet to prevent displacement of the material forming the frusto-conical member upon propulsion of the bullet, said frusto-conical restraining means being effective to act as a gas seal for the rearward portion of the shank of the bullet to increase bullet velocity and protect the inner end of the barrel bore against erosion by propellent gases.

5. In a bullet gun assembly for use in perforating a well casing or the like, said gun assembly being formed of a generally cylindrical body provided with at least one laterally extending opening forming an individual gun, the opening comprising an inner portion accommodating an explosive charge and ignition means, the explosive charge being an annular body having a central bore therethrough, and an enlarger outer portion in which is removably secured a generally tubular barrel member having a central bore forming a barrel with inner and outer ends, the inner end opposing the explosive charge, the central bore of the barrel adapted to receive a bullet, the improvement which comprises: a frusto-conical enlarged portion extending into the inner end of the barrel bore, a removable frusto-conical restraining member formed of steel positioned in the frusto-conical enlarged end portion of the barrel bore, the frusto-conical member having a central bore axially aligned with the axis of the barrel bore, a bullet having a nose and shank portion, with the forward portion of said shank portion positioned in said central bore of the frusto-conical member formed of steel, an annular metal cover in the inner portion of the gun abutting the large end of the frusto-conical restraining member, the annular metal cover having a peripheral flange engaging the wall of the inner portion and an internal flange engaging the shank of the bullet, the internal flange being of such thickness that it withstands the pressure of the propellent gases and remains in the gun upon firing, said frusto-conical restraining means being effective to protect the barrel bore against erosion by propellent gases.

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