April 11, 1944. E. F. RAYMOND 2,346,233

GUN PERFORATION IN WELLS

Filed April 24, 1942 2 Sheets-Sheet 1

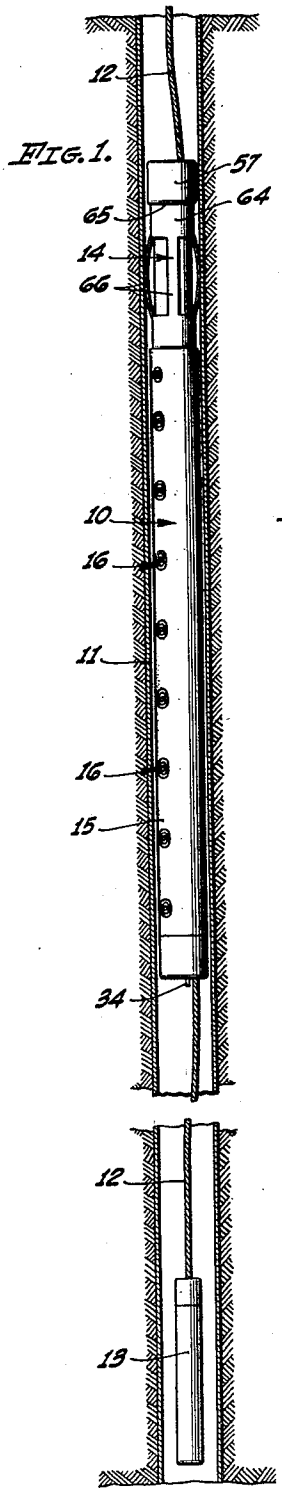


FIG. 1.

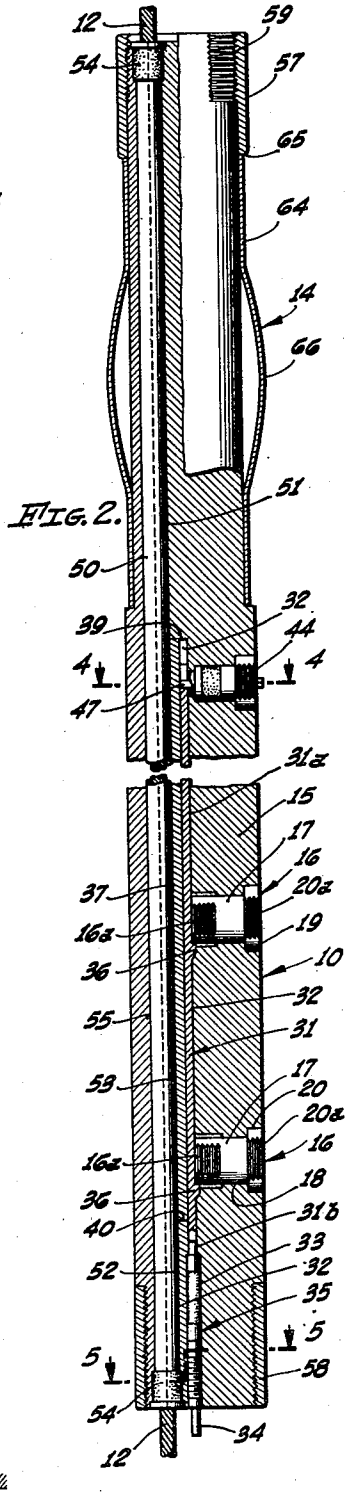


FIG. 2.

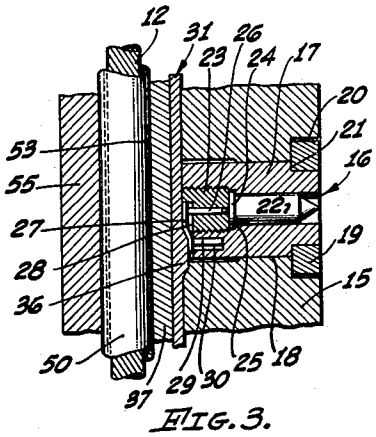


FIG. 3.

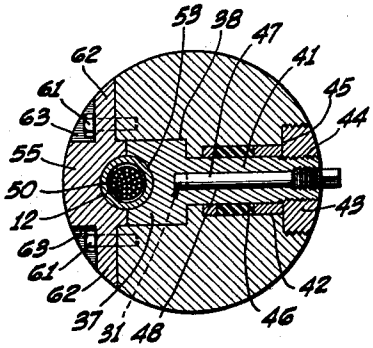


FIG. 4.

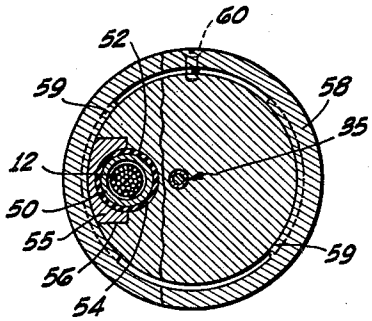


FIG. 5.

EDWARD F. RAYMOND,
INVENTOR
BY Calvin White
ATTORNEY.

April 11, 1944. E. F. RAYMOND 2,346,233

GUN PERFORATION IN WELLS

Filed April 24, 1942 2 Sheets-Sheet 2

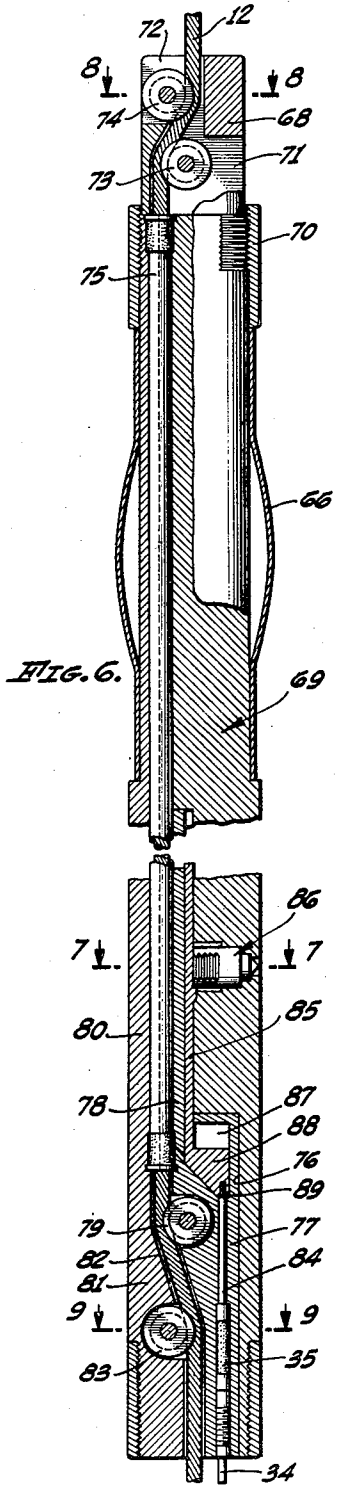


FIG. 6.

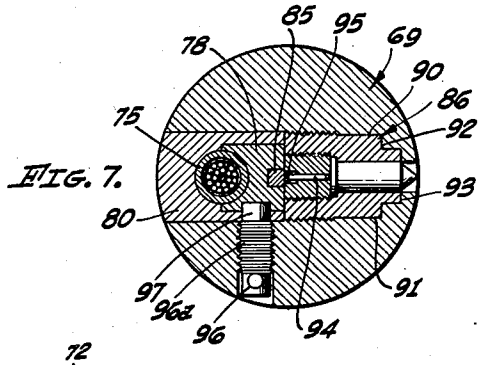


FIG. 7.

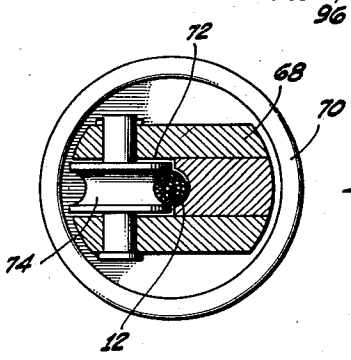


FIG. 8.

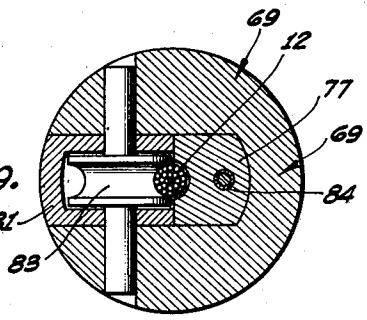


FIG. 9.

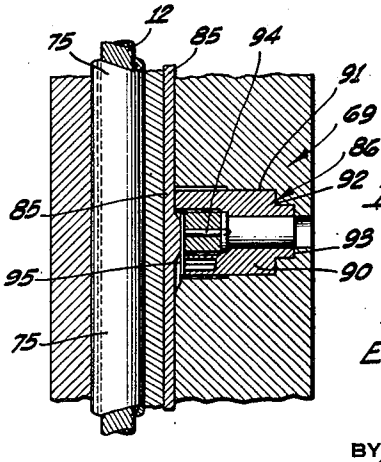


FIG. 10.

EDWARD F. RAYMOND,
INVENTOR

BY Malcolm White

ATTORNEY.

Patented Apr. 11, 1944 2,346,233

UNITED STATES PATENT OFFICE

2,346,233

GUN PERFORATION IN WELLS

Edward F. Raymond, Wilmington, Calif.

Application April 24, 1942, Serial No. 440,319

14 Claims. (Cl. 164—0.5)

This invention relates to the art of gun-perforating well pipe, in accordance with which the established practice has been to lower within the casing a gun-type perforator which may be controllably fired at a predetermined depth measurable from the ground surface.

One of the prevalent methods involves the use of an electrically fired gun perforator which is lowered (suspended) on a cable of sufficient strength to support the gun and containing electrical lead wires through which current is passed to control the firing of the gun. While functionally effective, the use of electrically controlled gun perforators has certain economic and practical disadvantages due to the cost and complexities of incidental equipment required for running and servicing the perforator, as well as the comparatively complicated construction of the gun itself. As an illustration, such perforators require the use of expensive, electrically equipped trucks, also the use of special and expensive cable, as well as trained operating personnel, all of which could desirably be dispensed with in favor of a gun capable of being run into and removed from the well by the use of standard equipment always available at the well rig.

Mention also may be made of prior proposals to use mechanically operated gun perforators, in which the gun is run in the well on a cable and fired by a mechanical means actuated by movement of the cable, as by an upward pull, in distinction to electrical firing by current passed through the cable. Although possessing certain advantages and economies by dispensing with the requirement for electrical equipment and special cable, such mechanically operated guns lack the simplicity of construction and adaptability to being run with ordinary well rig equipment, that are essentially important if the gun is to be universally usable.

My primary object is to provide an improved gun perforator of simple construction and capable of being run in the well and operated by the standard available equipment, thereby rendering the perforator capable of ready distribution and use at all locations and, as will appear, by operators requiring no particular training in its handling. Another and more specific purpose is to avoid necessity for the usual special suspension cables by enabling the perforator to be run into the well free of movable support from the ground surface. In accordance with the invention, the functions of a cable may be served by the usual sand line, available at the well rig, which is first run in the well to a predetermined depth, and subsequently employed in the firing and retrieving of the gun which is allowed to fall or otherwise move down along the cable to operating position.

In its preferred form, the perforator comprises an elongated body which may contain any desired number of individual gun units operable to perforate the casing at locations of suitable spacing and arrangement. The body is suitably adapted to move downwardly along the cable, or to be guided by the cable, as by providing the body with a longitudinal opening or bore through which the cable extends. In the broad aspects of the invention, the gun units may be fired simultaneously or sequentially by any suitable firing mechanism capable of actuation when or after the gun reaches a predetermined depth in the well at which the casing is to be perforated. Preferably, firing of the gun units is effected by engagement of the perforator, or of the firing mechanism, with an abutment carried by the cable in measured relationship to the casing area to be perforated. In this manner, the gun may be made to fire automatically by virtue of its downward movement into engagement with the cable-carried abutment. Thereafter, the gun may be retrieved by reeling the cable out of the well.

All the above mentioned features of the invention, as well as additional objects and details, will be understood to better advantage from the description to follow. Reference is had throughout the description to the accompanying drawings, in which:

Fig. 1 is a general view showing the perforator being run into the well about the cable or sand line;

Fig. 2 is an enlarged view of the perforator taken in vertical section along the gun units, the gun barrels however appearing in elevation;

Fig. 3 is a fragmentary enlarged section showing one of the gun units and the associated firing mechanism;

Figs. 4 and 5 are enlarged cross-sections taken on lines 4—4 and 5—5 of Fig. 2;

Fig. 6 is a view similar to Fig. 2 illustrating a variational form of the invention;

Figs. 7, 8, and 9 are enlarged cross-sections taken on lines 7—7, 8—8, and 9—9, respectively, of Fig. 6; and

Fig. 10 is a fragmentary sectional enlargement of the form of gun unit appearing in elevation in Fig. 6.

As illustrated in Fig. 1, the gun perforator assembly, generally indicated at 10, is adapted to

move downwardly within the well casing 11 while in engagement with and guided by a cable 12, preferably the usual sand line, which has been run into the well to predetermined depth in advance of the perforator. The cable 12, may carry at its lower end a suitable abutment 13, the primary purpose of which is to provide a relatively stationary body against which the firing mechanism of the guns may engage when the perforator reaches the depth, determined by the location of the abutment, at which the casing is to be opened. The gun perforator may be run into the well by restrained gravity drop, or otherwise caused to move downwardly within the casing, independently of any direct suspension from the ground surface. As illustrative, the diameter of the perforator body is shown to be sufficiently less than the internal diameter of the casing, to permit gravity fall of the perforator under the restraining influence of suitable speed regulating means, as generally indicated at 14.

Referring more particularly to Figs. 2 to 5, the body 15 of the perforator may be elongated to accommodate any suitable number and arrangement of the individual gun units, generally indicated at 16, the latter typically being shown in alined relation and adapted to be fired simultaneously, although broadly the invention is not limited in such respects. Each of the gun units 16 is shown to comprise a barrel 17 inserted within a transverse bore 18 in the body and retained therein by interrupted threads 16*a* and a lock bushing 19 engaged in the counterbore 20 by interrupted threads 20*a* and bearing against the barrel shoulder 21. After insertion of the cartridge 22, the rear of the barrel is closed by plug 23 confining the cartridge shell flange 24 against the barrel shoulder 25. Firing pin 26, extending within the bore of plug 23, is formed integrally with a flexible carrier 27 received within recess 28 formed in the inner ends of the barrel and plug, the carrier 27 in turn having an integral finger 29 projecting within an opening 30 in the barrel below the plug. As will appear, pin 26 is advanced to fire the cartridge by deflection of the flexible carrier piece 27. Finger 29 serves as a guide for the carrier and pin assembly, and has sufficient displaceability in bore 30 to accommodate deflection of piece 27 in the firing operation.

The gun units 16 are fired by a trigger or elongated firing rod 31 received within a recess 32 in the later described guide member 37, the rod extending at its lower end through body bore 33 to a terminal 34 projecting below the bottom end of the body. The portion 31*a* of the firing rod contained within recess 32 preferably is polygonal, or substantially square in cross-section, whereas the lower end portion 31*b* of the rod extending through bore 33 may be round in section to facilitate sealing off by a suitable packing gland assembly, generally indicated at 35. The rod 31 is formed with a series of projections 36 received within recesses 28 and engageable with the flexible pieces 27 upon upward displacement of the rod, to thrust pins 26 into firing engagement with the cartridges 22.

The body has a longitudinal recess 38 containing a guide member 37 between shoulders 39 and 40 (see Fig. 2), member 37 in turn containing the above mentioned recess or groove 32 which receives the firing rod 31. Member 37 may be suitably retained in position, as by an integrally formed bolt 41 (see Fig. 4) projecting outwardly within the body bore 42 and secured in place by a bushing 43 threaded at 44 on the bolt and bearing against the body shoulder 45. Suitable packing 46 may be provided to seal the bolt against fluid entry along its exterior. During assembly of the gun, the rod 31 may be locked against displacement in a firing direction by means of pin 47 threaded into bore 48 of the bolt and projecting into groove 32 above the end of the rod, as illustrated in Fig. 2. When the gun is to be run into the well, pin 47 may be withdrawn to free the firing rod for upward movement.

The cable 12 passes through the body within a protector tube 50 partially received within body recesses 51, 52, and within recess 53 in the guide member 37, the ends of the tube 50 being sealed by suitable packing glands 54. The assembly consisting of the firing rod, guide member, and cable protector tube is retained within the body by a locking piece 55 extending the full length of the body and received within the outer portion of recess 38, as shown in Fig. 4. Above and below the guide member 37, the locking piece 55 is received within shallower body recesses, as indicated at 56 in Fig. 5. The ends of piece 55 are confined to the body within sleeves 57 and 58 having interrupter threads 59 engaging body threads of corresponding angularity (see Fig. 5), and suitably locked against rotation, as by set screws 60. If desired, the locking piece 55 may have other or additional connections with the body, as by means of screws 61 passing through lugs 62 formed integrally with the carrier piece and received within recesses 63.

The speed control 14 provided to govern the rate of descent of the perforator within the casing, may comprise a sleeve structure 64 confined between shoulders 65 and the end of sleeve 57, and having intermediate bowed areas 66 engaging the casing with a tightness dependent upon the radial spread of the bows. This spread, and therefore the frictional resistance against free-falling of the perforator within the casing, is controllable by adjustment of sleeve 57 to vary the degree of longitudinal compression and expanded condition of the sleeve.

The variational form of the invention shown in Figs. 6 to 10 differs from the described embodiment primarily with respect to the cable course within and in relation to the body axis, and in the specific form of the gun units. In Figs. 1 and 2, the cable is shown to be run through the body in a straight course offset from the body axis, i. e., its longitudinal center. Where it is desirable to maintain alinement between the body and cable, the latter may be brought to enter and leave the ends of the body at its axial center by simple arrangement of sheaves, as shown in Fig. 6. Here the upper end 68 of the body 69 is extended above the sleeve 70 and is recessed at 71 and 72 to accommodate the sheaves 73, 74 and the cable deflection from the axial center of the body into alinement with the protector tube 75. The lower portion of the body is recessed at 76 to contain the enlarged lower end portion 77 of the guide member 78, and the latter in turn is recessed to contain the upper sheave wheel 79. The locking piece 80 has a lower enlargement 81 which, like the guide member enlargement 77, is recessed at 82 to accommodate the cable, the enlargement 81 being further recessed to contain the lower sheave 83. In this instance the lower end of the protector tube 75 may be terminated a short distance above the upper sheave 79.

The location of the sheaves 79 and 83 necessitates offsetting the lower portion of the firing

rod 84 with relation to its upper extent 85 alined with the gun units 86. For this purpose, the guide member enlargement 77 may be recessed at 87 to accommodate and guide an intermediate enlargement 88 of the firing rod, into which the bottom circular cross-section portion 84 is threaded as at 89.

The specific form of the gun unit 86 shown in Figs. 7 and 10 differs from that previously described, with respect to certain simplifications and the adaptability of each entire gun unit to be inserted and securely retained within its bore by installation from the inside. Here the gun barrel 90 threaded into bore 91 may be taken up tightly against shoulders 92 and 93, to the elimination of the outside lock bushing of the first described form. Otherwise, the inner end formation of the barrel assembly and its association with the firing pin 94, the flexible carrier 95, and the firing rod 85 are the same as previously described. Fig. 7 illustrates an additional or variational way of locking the guide member 76 and locking piece 80 in place within the body. Both elements may be locked in position by a pin 96 threaded at 96a into the body, with the end of the pin projecting at 97 within alined openings in the guide member and locking piece.

Referring to the first described form as illustrative, the perforator is assembled to be run in the well by first inserting the gun units 16, followed by the firing pin assemblies 27, firing rod 31, and guide member 37, with the latter locked in place by bolt 41 and the firing rod restrained against accidental tripping by insertion of the locking pin 47. Thereafter, the protector tube that has been placed about the cable run in advance into the well, is inserted within the body, the locking piece 55 placed in position, sleeve 64 applied, and the end sleeves 47 and 48 screwed onto the body to lock the assembled parts in operating condition.

Assuming the abutment 13 to have been lowered on the cable to the desired predetermined position, the gun assembly is dropped into the casing and permitted to fall under restraint of the speed control 14. Upon engagement of its lower projecting end 34 with the abutment, the firing rod is displaced upwardly to discharge simultaneously the individual gun units and thereby perforate the casing. As will be apparent, the perforator is then retrievable from the well simply by reeling up the cable on the usual sand line drum.

I claim:

1. A gun perforator for use in wells, comprising an elongated body movable downwardly along a cable lowered in the well in advance of the perforator, a plurality of gun units positioned in the body at right angles with the body axis and spaced at intervals longitudinally thereof, a firing member displaceable in a vertical direction within the body, and means contained in each of said gun units and coacting with said member to cause all of said gun units to be fired by movement of the member in said direction.

2. A gun perforator for use in wells, comprising a body adapted to travel downwardly while free of movable support from the top of the well, along a cable lowered in the well in advance of the perforator, a plurality of gun units positioned laterally in the body at longitudinally spaced intervals to discharge from the side thereof, and firing means extending vertically within a length of the body occupied by said gun units and displaceable in one direction to fire all of the units and each independently of the firing of the others.

3. A gun perforator for use in wells, comprising a body movable downwardly along a cable lowered in the well in advance of the perforator, said body containing a longitudinal opening adapted to receive said cable, a plurality of gun units positioned laterally in the body to discharge from the side thereof, correspondingly spaced firing pins in said units and spaced longitudinally of the body, and a vertically movable elongated firing member extending longitudinally in the body and projecting out of one end thereof, said member coacting with said firing pins to fire all of said gun units as a result of vertical movement of said member in one direction.

4. A gun perforator for use in wells, comprising a unit body adapted to move downwardly along a cable lowered in the well in advance of the perforator, a plurality of gun units carried by said body, and coacting means carried by said body and cable for firing all of said gun units and each unit independently of the firing of the others, automatically when the perforator reaches a predetermined depth in the well.

5. A gun perforator for use in wells, comprising a unit body adapted to move downwardly along a cable lowered in the well in advance of the perforator, a series of gun units carried by the body at spaced longitudinal intervals, and coacting means carried by said body and cable for firing all of said gun units automatically when the perforator reaches a predetermined depth in the well, said means comprising means upwardly displaceable in the body, to coact with and fire each gun unit independently of the firing of the others.

6. A gun perforator for use in wells, comprising a body movable downwardly along a cable lowered in the well in advance of the perforator, said body containing a longitudinal opening to receive and pass the cable, a vertical series of spaced gun units, a removable member backing said gun units, and an elongated firing rod between said member and the gun units and extending from below the body through a length of the body occupied by said units, said firing member being upwardly displaceable in the body by engagement with an abutment in the well to fire all of said units.

7. A gun perforator for use in wells, comprising an elongated body movable downwardly along a cable lowered in the well in advance of the perforator, said body containing a longitudinal opening to receive and pass the cable, a plurality of gun units spaced longitudinally of the body axis and extending at substantially right angles therewith, firing pins in said gun units, a firing member upwardly displaceable in the body by lowering against an abutment in the well, and cam means carried by said member and coacting with each of the gun unit firing pins to cause such upward displacement of said member to fire all of said units.

8. A gun perforator for use in wells, comprising an elongated body movable downwardly along a cable lowered in the well in advance of the perforator, means for passing the cable through an opening in said body, a series of gun units in the side of said body and positioned at spaced intervals longitudinally of the body, an abutment carried by said cable, and elongated firing means extending within the body past said gun units, said firing means being upwardly displaceable within the body by engagement with said abut-

ment and thereby caused to coact with and fire all of said units.

9. A perforating gun comprising: a body having an end which is a part of said body; the body having a sealed chamber in said end; a plunger reciprocably mounted in said end to extend into said chamber and having an anvil adapted to be hit as a body falls to actuate the plunger in said chamber; a gun barrel supported in the body for the discharge of a cartridge laterally thereof; and firing mechanism for said barrel including an actuating rod projecting into said chamber and engaged by the end of said plunger for movement thereby to actuate said rod to actuate a firing pin to fire said cartridge, when said plunger is struck.

10. A gun perforator for use in wells, comprising a body adapted to move downwardly along a cable lowered in the well in advance of the perforator, a plurality of gun units carried by said body, and coacting means carried by said body and cable for simultaneously firing said gun units automatically when the gun units reach a predetermined depth in the well.

11. The combination comprising a cable lowered in a well, and a gun perforator including a body movable downwardly along the cable, means engaging the cable to restrain free-falling movement of the body, a gun unit, and means for firing said gun unit.

12. A gun perforator for use in wells, comprising a body movable downwardly along a cable lowered in the well in advance of the perforator, said body containing a longitudinal opening to receive and pass the cable, yieldable guide means carried by the body and engageable with the wall of the well, a laterally positioned gun unit, and means operable by lowering the perforator against an abutment in the well for firing said gun unit.

13. A gun perforator for use in wells, comprising a body movable downwardly along a cable lowered in the well in advance of the perforator, means for passing the cable into and out of the body in axial alinement therewith and for passing the cable through an opening intermediate the ends of the body in offset relation to the body axis, a gun unit, and means for firing said gun unit.

14. A gun perforator for use in wells, comprising a body movable downwardly along a cable lowered in the well in advance of the perforator, said body containing a longitudinal opening to receive and pass the cable, a series of laterally positioned gun units, an elongated removable member backing said gun units, and a vertically displaceable firing member adjacent said gun units and projecting below the body, said firing member being adapted to engage an abutment in the well to fire said gun units.

EDWARD F. RAYMOND.