Dec. 14, 1943. G. F. TURECHEK 2,336,819

METHOD AND APPARATUS FOR PERFORATING WELL CASINGS BY GUNFIRE

Filed Feb. 24, 1943

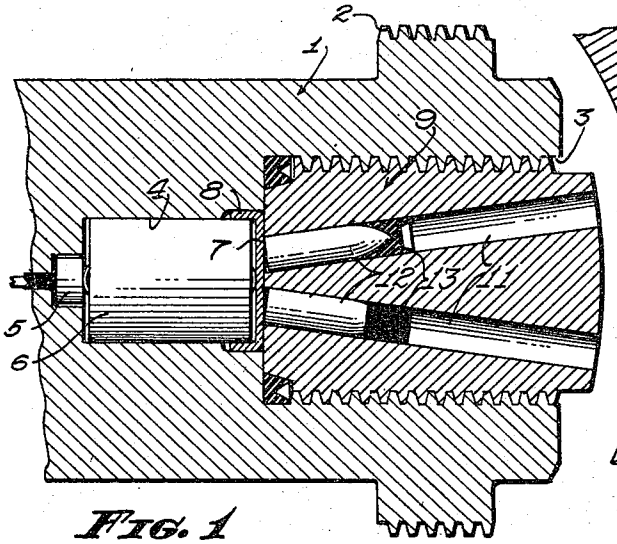


FIG. 1

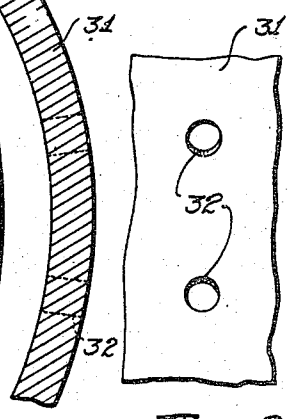


FIG. 2

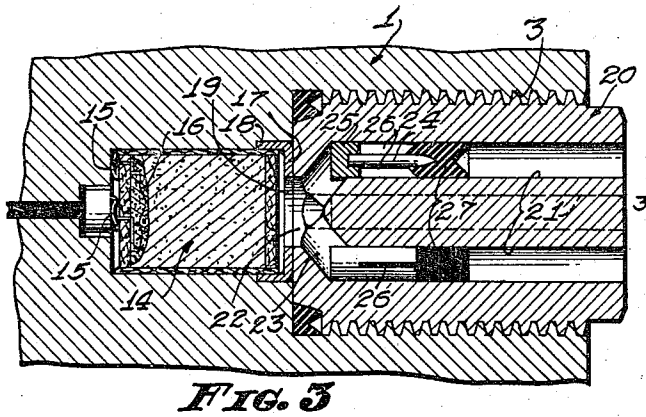


FIG. 3

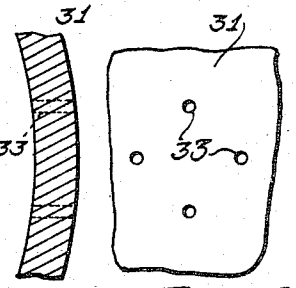


FIG. 4

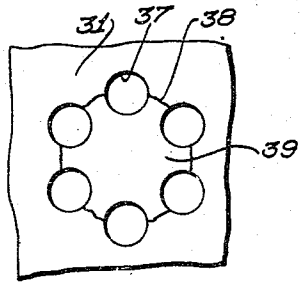


FIG. 5

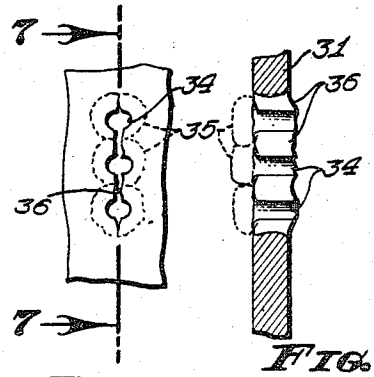


FIG. 6

FIG. 7

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METHOD AND APPARATUS FOR PERFORATING WELL CASING BY GUNFIRE

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11 Claims. (Cl. 164—0.5)

My invention relates to methods and apparatus for perforating well casing by gunfire, and among the objects of my invention are:

First, to provide a method and apparatus adapted to utilize and incorporate a conventional gun perforator wherein the apparatus comprises a multiple bore gun barrel capable of being utilized interchangeably with a conventional gun barrel of a conventional gun perforator;

Second, to provide an apparatus which is particularly adapted to fire small diametered bullets through well casing in a quantity exceeding the number conventionally fired in a standard round or cycle of operation, so that reduction in size of perforations need not entail a corresponding reduction in the total or combined area of perforations;

Third, to provide a method and apparatus of perforating well casing wherein slits, as distinguished from round openings, may be formed in the casing, directed along any prearranged plane, with a minimum reduction in the strength of the casing, thereby forming by gunfire with the casing in situ the type of opening formerly accomplished only by preslotting or milling operations on the casing before its insertion in the well;

Fourth, to provide a method and apparatus which is particularly effective in avoiding sand difficulties formerly created by large round gun perforator openings of standard diameter, as the size of openings may be reduced to meet conditions; for example, holes as small as one-sixteenth inch in diameter may be made in quantities;

Fifth, to provide a method and apparatus whereby openings materially larger than have heretofore been possible by means of a gun perforator may be made in the casing, either for the purpose of weakening the casing for salvage purposes or facilitating production from formation of low porosity; and

Sixth, to provide a removable multiple bore gun barrel for gun perforations wherein the gun bores may extend radially from the gun body or parallel with respect to each other.

With the above and other objects in view, as may appear hereinafter, reference is made to the accompanying drawing, in which:

Figure 1 is a fragmentary longitudinal sectional view through a typical gun perforator unit such as shown in my previous patent, No. 2,092,294, issued September 7, 1937, showing one form of my multiple bore gun barrel;

Figure 2 is a fragmentary inside view of a casing showing the type of perforations made by bullets from the gun barrel shown in Figure 1;

Figure 3 is a fragmentary sectional view similar to Figure 1, but showing a modified form of gun barrel and bullets therefor;

Figure 4 is a fragmentary inside view of a casing similar to Figure 2, showing the bullet pattern made by the gun barrel arrangement of Figure 3;

Figure 5 is a fragmentary inside view of a casing showing another bullet pattern wherein the bullet perforations are sufficiently close that the intervening webs of casing have broken out;

Figure 6 is a fragmentary inside view of a casing showing another bullet pattern whereby the casing is caused to split longitudinally to form a slot of narrow width; and

Figure 7 is a sectional view thereof taken through 7—7 of Figure 6.

The features of my gun perforator are particularly adapted to be utilized in conjunction with a gun perforator construction of the type shown in Lane 2,062,974, issued December 1, 1936, or the gun unit construction shown in my previous Patent No. 2,092,294, issued September 7, 1937, but may however be incorporated in any type of a gun perforator having a removable barrel.

With reference first to Figure 1, there is illustrated fragmentarily the gun block 1 of a gun unit of the type disclosed in the above mentioned patents. The gun block is adapted to be fitted into a gun body and for this purpose is provided with external threads 2, or the gun block 1 may be an integral part of the gun body. One end of the gun block is provided with an internally threaded barrel socket 3, at the inner end of which is a cartridge chamber 4 of reduced diameter. In the base of the cartridge chamber is mounted an insulated contact pin 5, and within the cartridge chamber is positioned an explosive cartridge 6 containing a fuse wire (not shown) adapted to be ignited electrically. The outer end of the cartridge chamber 4 is covered by a shear disk 7 having a skirt 8 directed into the cartridge chamber around the outer end of the cartridge 6, the cartridge chamber being enlarged slightly at its outer end to accommodate the skirt.

The threaded barrel socket 3 receives a gun barrel 9 which is externally threaded and the inner end of which seats against the shoulder formed between the barrel socket 3 and cartridge chamber 4. A sealing gasket is provided at the inner end of the threads which join the gun barrel and gun block.

The structure described to this point may be considered as conventional, the present invention being directed particularly to the construction of the gun barrel 9 and the method of utilizing certain arrangements of the gun bores therein. The gun barrel 9 is provided with two or more gun bores 11. As shown in Figure 1, the gun bores diverge from the rear to the muzzle end of the gun barrel, their inner ends being close together and within the projected area of the cartridge chamber 4. The gun bores 11 are smaller in diameter than has heretofore been the conventional practice in gun perforators, but their combined cross sectional areas may approach that of the conventional bore of a gun perforator barrel.

It has been found, from extensive operation of gun perforators, that the optimum diameter of the gun bore is approximately one-half inch, although gun bores as small as a fourth of an inch have been used as well as sizes larger than one-half inch. The preferred size of the gun bore has been dictated by the strict limitations in the size of the gun perforator. As the bore diameter is reduced the powder pressure is increased, assuming that no change is made in the size of the cartridge chamber. The powder pressure is increased for the simple reason that it is generated faster than it can be utilized; as a result the decrease in diameter of the gun bore decreases the efficiency of the gun perforator. While the velocity will increase as the diameter is reduced, the increase is due to a reduction in mass; furthermore, the velocity does not increase in proportion to decrease in diameter, so there is a net loss of penetrating power which is cumulative with the reduction in mass.

However, it has been possible to utilize single bores in gun perforators as small as a fourth of an inch in those cases in which only a single string of casing is to be penetrated. This is accomplished however not only with a loss of efficiency, but with increased strain on the gun perforator and an attendant shortening of its useful life. Furthermore, in those cases where a smaller hole is desired a larger number of shots are required in order to obtain the required total perforation area. Thus, heretofore four disadvantages have existed in the use of small bored gun perforators:

1. Increased powder pressure, tending to decrease the gun life.

2. Increase in the number of shots required in order to obtain the necessary total perforation area.

3. Decrease in penetration due to reduced efficiency of the propelling force on the bullet.

4. Decrease in penetration due to reduction in the weight of the bullet.

With my present invention three of the above disadvantages are overcome, or at least reduced in magnitude. The area of a one-fourth inch bore is approximately one-fourth the area of a half inch bore. Therefore, four one-fourth inch bullets may be driven by a cartridge developing substantially the same powder pressure as one half inch bullet. A one-fourth inch bullet is not driven at the material expense of effective pressure on the other bullet, but rather by what would otherwise be the excessive pressure building up in the cartridge chamber and of no practical benefit. While four bores may be used, five, three or two bores may be provided, the latter case being illustrated in Figures 1 and 2 wherein the casing 31 is provided with holes 32 therein spaced a substantial distance apart by reason of the diverging arrangement of the gun bores.

Each of the bullets 12 seats against the shear disk 7 and their outer ends are covered by seal plugs 13 to exclude well fluids. The sections of the seal disk covering each gun bore rupture when the powder pressure in the cartridge has built up to some predetermined value, and therefore with the construction shown in Figure 1 the advantage of "delayed fire" discussed in my previous patent referred to above is obtained.

Reference is now directed to Figures 3 and 4. In this construction an explosive cartridge 14 is shown which differs from the cartridge 6 in that both terminals 15 are arranged at the rear end and are connected by an igniting element 16. Also, as in the first described structure, the outer end of the cartridge chamber 4 is provided with a seal disk 17 having a skirt 18. The disk may be solid similar to the disk 8, or may be provided with a central opening 19 therein.

The modified gun barrel 20 fits within the barrel socket 3. In this case the gun barrel is provided with gun bores 21 which are parallel to each other. The inner end of the gun barrel is provided with a recess 22 which registers with the opening 19 in the seal disk and which communicates with the gun bores 21 through ports 23. Bullets 24 fit within the gun bores. The bullet shown in Figure 3 is smaller than the gun bore and each bullet is fitted in a bullet holder 25 formed of relatively soft and light material such as aluminum. The bullet holder is provided with a socket which receives the bullet. The base of the holder is solid but the side walls are provided with slips 26 to facilitate breaking up of the holder when the holder and bullet strike the surrounding casing. A plug 27 covers the outer end of each bullet and seals the gun bore.

The bullets shown in Figures 1 and 3 are, of course, interchangeable in the gun bores 11 and 21. Bullets as small as $\frac{1}{8}$" in diameter have been successfully fired through casing by use of the holder as shown in Figure 3. However, some 60 $\frac{1}{8}$" holes are required to equal the area of one $\frac{1}{2}$" hole, or some 15 $\frac{1}{8}$" holes to equal one $\frac{1}{4}$" hole. It is of course obvious that there is a limitation in the ratio of the diameter of the bullet to the diameter of the gun bore, that is, the wall thickness of the holder is limited. Practically, the bore can not be appreciably larger than $\frac{1}{4}$" in order to handle a $\frac{1}{8}$" bullet. Thus, all of the problems confronting the use of a $\frac{1}{4}$" bore are present in the use of a $\frac{1}{8}$" bullet, and this is magnified by the fact that the number of openings in the casing required is increased enormously. In fact, the increase is so great that, in spite of the practical need for small perforations, the cost has heretofore been prohibitive.

Inasmuch as it is feasible to use 4, 5, or even 6 $\frac{1}{4}$" bores the cost can be reduced one-fourth, one-fifth or one-sixth, of the present cost for a given total perforation area. In Figure 4 the casing 31 is shown with four perforations 32 arranged in a pattern determined by the gun bore placement shown in Figure 3.

It should be noted that the powder pressures in the gun bores are substantially equal at all times. Consequently, the wall thickness between the bores may be quite thin; for example, the third bore shown in Figure 3 as offset backwardly from the section through which Figure 3 is taken, may actually be in a plane with the top and bottom

bores so that the bullet holes may be placed close together, as shown in Figures 6 and 7.

Although the bullet holder is made of soft material and does not penetrate the casing, the mass of the holder as it strikes the casing plus the pressure behind it places the casing under considerable local stress. Such stress, however, is insufficient to split the casing if the perforations are spaced as shown in Figure 4, that is, approximately three times the diameter of the gun bore from center to center. If the gun bores are grouped materially closer, for example, spaced about one and one-half the bore diameter, the cumulative local stresses exerted by the penetrating and non-penetrating parts of the bullet may, if desired, be built up to the point that the casing may be split between the perforations, as shown in Figures 6 and 7. In Figures 6 and 7 a casing **31** is shown perforated by holes **34** which are close enough that the masses of the non-penetrating holders indicated by **35** exert a substantially continuous force against the casing from the upper to the lower perforation. This causes the casing to form a slit as indicated by **36**. If the gun barrel is arranged so that the perforations extend longitudinally with respect to the casing the tensile strength of the casing is not appreciably weakened by the slit; in fact, is weakened much less than it would be if a round perforation equal to the area of the slit were made in the casing. Long prior to the introduction of gun perforating, liners slotted at the surface before being introduced in the well bore were used and are used at the present time, and it is well established that slots directed longitudinally with respect to the casing are preferred to round holes. However, heretofore it has been impossible to obtain a narrow slit, as shown in Figures 6 and 7, by the use of a gun perforator. The slit is, of course, materially larger than the combined areas of the perforations, so that fewer slots are required to obtain the desired perforation area. Preference for the slit or slot, as distinguished from the round perforation, is due not only to the increased strength of the casing, but also to the fact that all the advantages of small openings to restrict entrance of sand is obtained from a slit of the same width.

Quite another operation may be accomplished by means of the multiple bore gun perforator shown in Figures 1 or 3. In some instances a large hole, rather than a small hole, is desired in the casing. For example, some gun perforators have been used for the purpose of severing a casing, this being accomplished by firing a large number of shots in the same peripheral section of the casing, usually while placing a tensional strain on the upper end of the casing so that when the casing has been weakened the portion above may be removed for salvage. Also, large holes have been needed in some oil fields where the porosity of the formation was low and the nature of the formation did not require a strong casing. As pointed out before, the optimum diameter of the bullet is approximately ½", although $\frac{3}{16}$" and ⅝" bullets have been fired with success. Heretofore openings slightly larger than ⅝" have been obtained by using relatively soft bullets which "mushroom" and therefore break or tear an opening rather than pierce an opening in the casing. This is of course accomplished with a very great loss in penetrating ability. By arrangement of the gun bores close together and about a common center, openings **37** may be formed in the casing **31**, as shown in Figure 5, close enough that the webs between the openings tear as indicated by **38**, thus breaking out the entire center **39**. The openings **37** in Figure 5 are shown as made by full diametered bullets of the type shown in Figure 1 as it is the more applicable of the two bullet arrangements for this purpose; however, the bullet and holder arrangement shown in Figure 3 may be used.

It is obvious that only a few of these shots are required to completely sever a casing, or if properly spaced insure adequate drainage into the casing from formations of low porosity. In addition, each of the bullets penetrates further into the formation than does a mushroom bullet; therefore, a region of fairly high porosity is formed outside of the opening, very materially increasing the drainage area.

Various changes and alternate arrangements may be made within the scope of the appended claims, in which it is my intention to claim all novelty inherent in the invention.

I claim:

1. In a gun perforator adapted to fire bullets in a surrounding casing: a body structure defining a gun barrel socket and a cartridge chamber at the inner end of said socket; an explosive cartridge fitting said chamber; a gun barrel screw-threaded into said socket, said gun barrel having a plurality of gun bores diverging from the cartridge chamber end of said barrel to the muzzle end thereof; and bullets adapted to be discharged simultaneously from said gun bores under urge of said explosive charge.

2. In a gun perforator adapted to fire bullets in a surrounding casing; a body structure defining a gun barrel socket and a cartridge chamber at the inner end of said socket; an explosive cartridge fitting said chamber; a gun barrel screw-threaded into said socket, said gun barrel having a plurality of parrallel gun bores, and manifold passages from their rear ends to said cartridge chamber; and bullets adapted to be discharged simultaneously from said gun bores under urge of said explosive charge.

3. In a gun perforator adapted to fire bullets in a surrounding casing: a body structure defining a gun barrel socket and a cartridge chamber at the inner end of said socket; an explosive cartridge fitting said chamber; a gun barrel removably fitting said socket, said gun barrel having a plurality of gun bores communicating with said socket; a plurality of bullets of smaller diameter than the gun bores; and an adaptor surrounding each bullet for spacing said bullet in its gun bore.

4. In a gun perforator adapted to fire bullets in a surrounding casing: a body structure defining a gun barrel socket and a cartridge chamber at the inner end of said socket; an explosive cartridge fitting said chamber; a seal disk covering said cartridge; a gun barrel fitting said socket, said gun barrel defining a plurality of gun bores having independent breech ends within the area of said seal disk and diverging therefrom to the muzzle end of said gun barrel; and bullets for said gun bores, said bullets initially resting against said seal disk.

5. In a gun perforator adapted to fire bullets in a surrounding casing: a body structure defining a gun barrel socket and a cartridge chamber at the inner end of said socket; an explosive cartridge fitting said chamber; a gun barrel screw-threaded into said socket, said gun barrel

having a plurality of gun bores diverging from the cartridge chamber end of said barrel to the muzzle end thereof; a plurality of bullets of smaller diameter than the gun bores; and an adaptor surrounding each bullet for spacing said bullet in its gun bore.

6. In a gun perforator adapted to fire bullets in a surrounding casing: a body structure defining a gun barrel socket and a cartridge chamber at the inner end of said socket; an explosive cartridge fitting said chamber; a gun barrel screw-threaded into said socket, said gun barrel having a plurality of parallel gun bores, and manifold passages from their rear ends to said cartridge chamber; a plurality of bullets of smaller diameter than the gun bores; and an adaptor for each bullet for spacing said bullet in its gun bore.

7. In a gun perforator adapted to fire bullets in a surrounding casing: a body structure defining a gun barrel socket and a cartridge chamber at the inner end of said socket; an explosive cartridge fitting said chamber; a gun barrel removably fitting said socket, said gun barrel having a plurality of gun bores communicating with said chamber; bullets adapted to be discharged simultaneously from said gun bores under urge of said explosive charge, the muzzle ends of said bores being spaced to define a ring and the diameters of said bores being such as to occupy a major portion of the mean periphery of said ring, whereby bullets spaced according to said bores and striking a well casing break out an opening substantially as defined by said ring.

8. The combination with a gun perforator wherein each gun unit has a removable single bore barrel, of a multiple bore barrel adapted to fit interchangeably with said single bore barrel, the total area of the several bores in said multiple bore barrel being substantially equal to the area of the bore in said single bore barrel.

9. In a gun perforator adapted to fire bullets in a surrounding casing: a body structure defining a gun barrel socket and a cartridge chamber at the inner end of said socket; an explosive cartridge fitting said chamber; a gun barrel removably fitting said socket, said gun barrel having a plurality of gun bores communicating with said chamber; bullets adapted to be discharged simultaneously from said gun bores under urge of said explosive charge, said bullets including penetrating elements of smaller diameter than said bores, and non-penetrating spacer elements holding said bullets centered in said bores, and wherein the muzzle ends of said bores define a line traversing the muzzle end of said gun barrel, the combined diameters of the gun barrels occupying the major portion of said line, whereby upon discharge of said bullets said non-penetrating elements place the well casing under bursting stress during penetration of said penetrating elements, thereby to split the casing a distance commensurate with the length of the line defined by said gun bore muzzles.

10. A method of perforating a well casing by gunfire, characterized by: simultaneously driving by gunfire against a surrounding casing a plurality of penetrating and non-penetrating projectiles spaced in a predetermined pattern.

11. A method of perforating a well casing by gunfire, characterized by: simultaneously driving by gunfire against a localized region of a surrounding casing a plurality of penetrating and non-penetrating projectiles to place the localized region defined by the points of penetration of said penetrating projectiles under stress calculated to split the casing within said region.

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