

March 3, 1953

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2,630,182

METHOD FOR SHOOTING OIL WELLS

Filed Feb. 19, 1947

2 SHEETS—SHEET 1

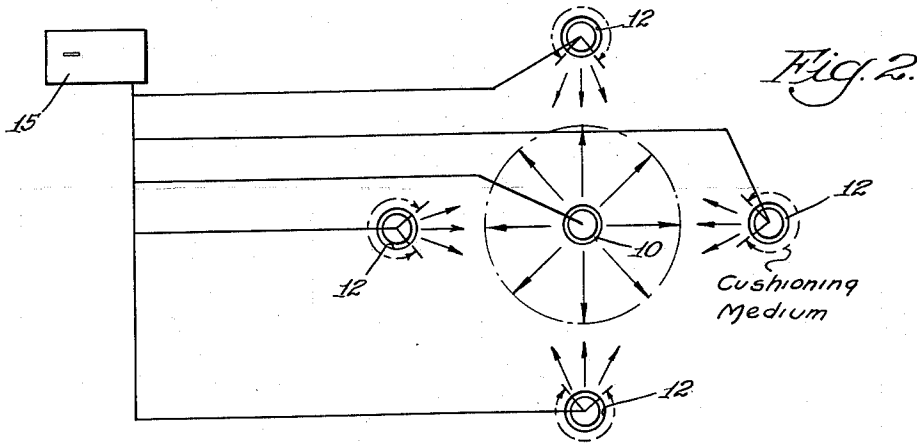
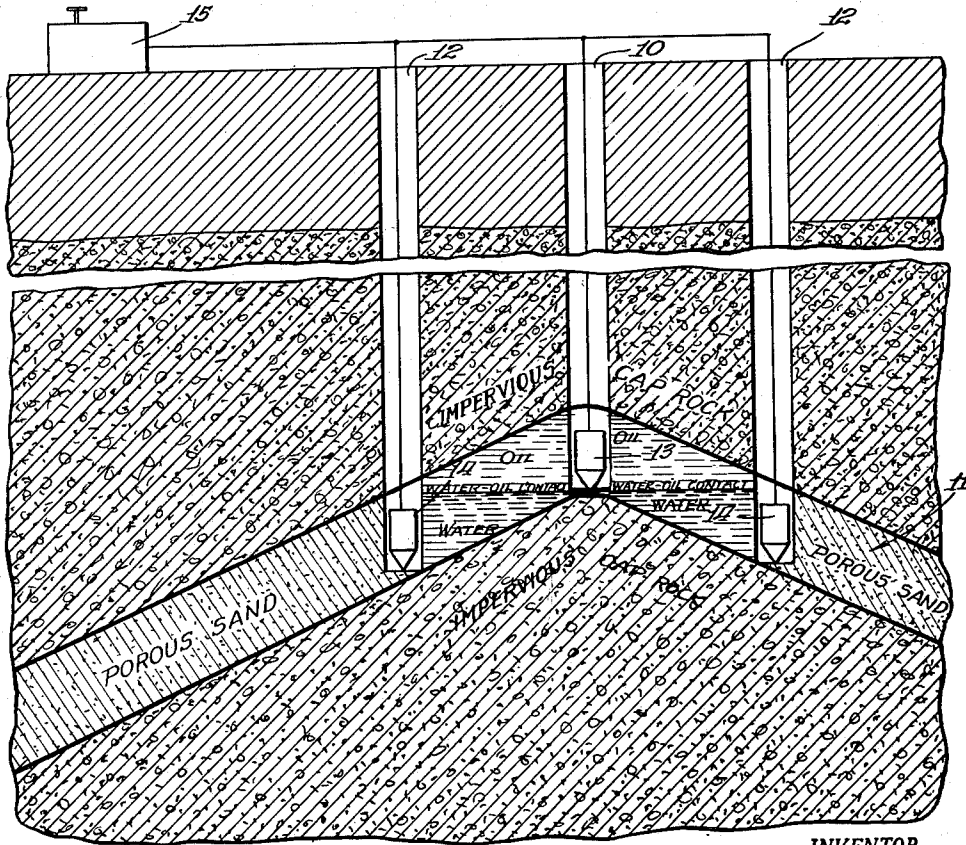


Fig. 1.

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2 SHEETS—SHEET 2

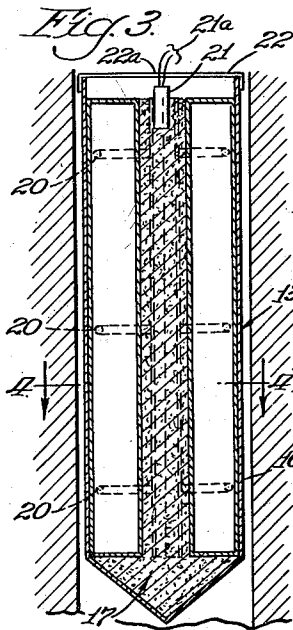


Fig. 3

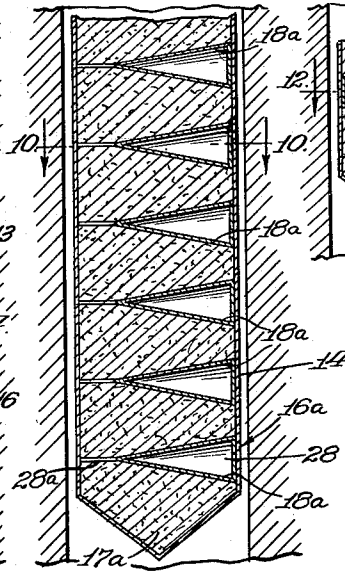


Fig. 9

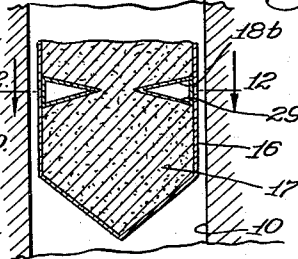


Fig. 11

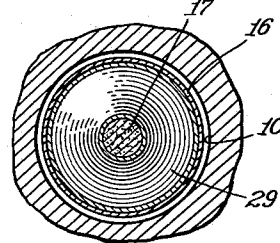


Fig. 12

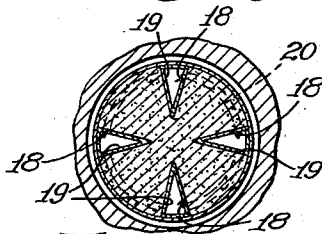


Fig. 4

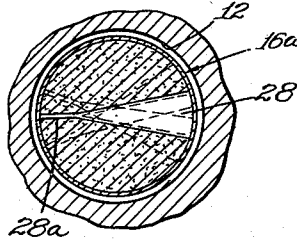


Fig. 10

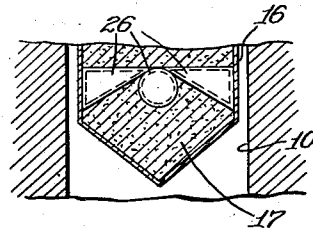


Fig. 7

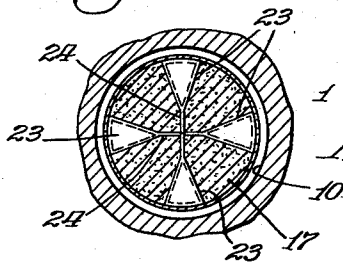


Fig. 5

Fig. 8

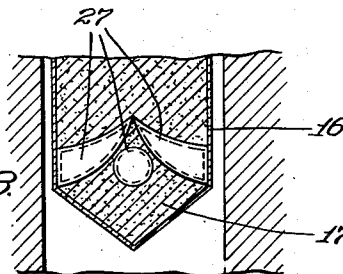
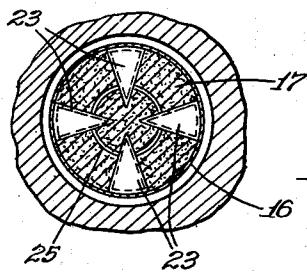


Fig. 6

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UNITED STATES PATENT OFFICE

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METHOD FOR SHOOTING OIL WELLS

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Application February 19, 1947, Serial No. 729,657

2 Claims. (Cl. 166—21)

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The present invention relates to improved methods and apparatus for shooting oil wells either to increase the primary productivity thereof or to facilitate stripping wells in old fields.

In general, oil well shooting falls into two classes, i. e., shooting new producing wells to increase primary production and the shooting of wells in old depleted fields to permit well stripping after primary production has stopped. In the first case, the object of shooting a well is to render a formation believed to be oil-bearing more permeable by cracking and breaking up the formation material from the hole outward through the side walls of the formation and into the formation. This has the effect of increasing or facilitating the flow of oil from the oil-bearing formation into the well. Shooting to increase the primary production in deep wells is usually accomplished by depositing a torpedo loaded with nitroglycerine, blasting gelatin or the like, alongside the oil-bearing formation with a time bomb; fluid, sand or cement tamping the torpedo; and then letting the time bomb detonate the explosive torpedo charge after the tamping operation is completed. In shallow well shooting, fluid tamping is usually used and detonation of the torpedo charge is effected by using "jack squibs," "torpedo bumpers" or electrical facilities instead of time bombs. The size of the explosive charge used in shooting wells to increase primary production may range from one hundred pounds to two thousand pounds or more, depending upon the thickness of the probable producing formation and the character (hardness) of the formation. The second general class, well stripping, is often carried out by drilling water wells at points surrounding the well or by using former oil wells which surround the oil well but have turned to water. These water wells are then used to force water under pressure into the oil bearing formation so that the oil is lifted up-structure and flows into the hole. Further, the forcing of water into the formation has the effect of maintaining the bottom hole pressure. This is known as water flooding. Here the increase of oil flow is augmented by shooting the water wells as well as the oil well itself.

Experts in the art of well shooting all agree that in shooting a well either to increase primary production or to strip the well, it is desirable to crack the formation material as far out from the side walls of the well as possible. They also agree that in shooting the water wells surrounding an oil well to be stripped, it is desirable to crack the formation material as far as possible toward the

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oil bearing part of the formation, but not to crack the formation material in directions away from the oil well since this increases the amount of water pumping which must be done in order to lift the oil into the well. It is also desirable to avoid increasing the permeability of so-called "by-passing" sands which may overlie the oil-bearing formation and reduce the efficiency of the water pumping operation by absorbing water. However, conventional shooting techniques do not permit such directionalized shooting. Moreover, there is serious doubt as to whether or not conventional shooting methods accomplish any cracking of the formation material. Thus many experts believe that since the explosive energy is uniformly dissipated in all directions radially outward from the well bottom, the only effect obtained is that of enlarging the hole by compressing the adjacent formation material. Such compression may have the effect of actually decreasing the porosity of the formation material instead of increasing it as desired. Regardless of the validity of this contention, it is definitely established that substantial cracking of the formation material (as measured in terms of increased well production) can only be obtained through the use of excessive quantities of explosive material.

It is an object of the present invention, therefore, to provide an improved method and improved apparatus for shooting oil wells to increase the productivity thereof, which obviates the above-described disadvantages of prior art methods and apparatus used for the same purpose.

It is another object of the invention to provide an improved method and improved apparatus for shooting an oil well and a group of surrounding water wells used in pressurized water flooding of the oil-bearing structure to effect an extensive cracking of the oil-bearing formation material in the oil well in all directions and to effect an extensive cracking of the same formation (but water-bearing) in the water wells in directions oriented towards the oil well (and not in other directions) whose flow it is desired to increase or whose pressure is to be maintained.

It is still another and more specific object of the invention to provide improved apparatus of the character described which is of low cost construction, minimizes the amount of tamping required, and provides for highly efficient utilization of the explosive material embodied therein.

The invention, both as to its organization and method of operation, together with further ob-

jects thereof, will best be understood by reference to the following specification taken in connection with the accompanying drawings in which:

Fig. 1 is a fragmentary sectional view taken along a vertical plane extending downward from the surface of the earth illustrating the manner in which the present invention is employed to shoot an oil well and surrounding water wells for the purpose of stripping the oil-bearing formation into which the oil well extends;

Fig. 2 is a top plan view illustrating the pattern of the oil well and surrounding water wells;

Fig. 3 is a fragmentary sectional view illustrating the details of one embodiment of the present improved apparatus for shooting the oil well shown in Fig. 1;

Fig. 4 is a sectional view taken along the lines 4—4 in Fig. 3 illustrating the cross sectional configuration of the device shown in Fig. 3;

Figs. 5, 6, 7 and 8 are sectional views illustrating different modifications of the device illustrated in Fig. 3;

Fig. 9 is a fragmentary sectional view illustrating the structure of the device which may be used for shooting the water wells surrounding the oil well shown in Figs. 1 and 2;

Fig. 10 is a sectional view taken along the lines 10—10 in Fig. 9;

Fig. 11 is a fragmentary sectional view illustrating a modification of the device shown in Fig. 3; and

Fig. 12 is a sectional view taken along the lines 12—12 in Fig. 11.

Referring now to the drawings and more particularly to Figs. 1 and 2 thereof, the present invention is there illustrated in its use to crack the subsurface oil-bearing formation material in an old depleted oil well 10 which is to be stripped by the water flooding method referred to above. More specifically, the well 10 extends from the surface of the earth downward into an oil-bearing formation 11 in the earth's crust. To flood this formation for the purpose of lifting the oil therein and causing the same to rise in the bottom of the well 10, a plurality of water wells 12 are drilled in the earth at points radially displaced from and surrounding the well 10 to a depth slightly greater than the depth of the oil well, i. e., into the water-bearing part of the formation 11. As explained above, in order to increase the flow of oil from the structure 11 into the bottom of the well 10 and to force the water (introduced into the wells 12 under pressure by suitable pumping equipment, not shown) to flow into the oil-bearing portion of the formation 11, it is highly desirable to crack up the formation material disposed between the well 10 and the water wells 12.

In accordance with the present invention this is accomplished by depositing at the bottom of the oil well 10 an explosive charge 13 having cavities along the sides thereof which have the effect of concentrating and directing radially outward from the longitudinal axis of the well the explosive forces developed upon detonation thereof, and depositing additional charges 14 at the bottoms of the water wells 12 having cavities therein generally facing the oil well 10 which have the effect of concentrating and directing toward the well 10 the explosive forces developed upon detonation thereof. Preferably the cavities in the charges 13 and 14 are so arranged that the explosive forces developed upon detonation thereof are directionalized along

the paths indicated by the arrows in Fig. 2 of the drawings.

In the illustrated arrangement, electrical detonation of the charges 13 and 14 is utilized, each charge being equipped with the usual electrical detonating cap, the ignition element of which is cable conductor connected to a detonating device or blasting machine 15 of the well known electric impulse type. This device is disposed at the earth's surface at a convenient point adjacent the wells 10 and 12. Although the charges 13 and 14 are illustrated as being connected for simultaneous detonation, it will be understood that they may be detonated one at a time in any desired order as convenience may dictate. It will also be understood that electrical detonation of the charges is illustrated by way of example only. Thus, any or all of the charges may be detonated through the use of torpedo bumpers, time bombs or jack squibs if required by the conditions encountered. Such directionalization of the explosive forces may be obtained by utilizing shooting devices or charges 13 and 14 of the improved form illustrated in Figs. 3 to 12, inclusive, of the drawings.

For the well 10, it is desirable to use a device 13 having four or more equi-angularly spaced cavities spaced along the sides thereof in order to produce directionalization of the explosive forces developed upon detonation of the device in several different directions. This may be accomplished by using the device 13 illustrated in Figs. 3 and 4 of the drawings. In brief, this device comprises an elongated sheet metal container 16 having a column of explosive material 17 therein, the sides of which are provided with a plurality of equi-angularly spaced V-shaped cavities 18 (four illustrated, but others may be added) which extend continuously through the length of the column and project inwardly from the outer surface thereof. Preferably the cavities 18 are formed in the sides of the explosive column 17 by providing V-shaped metal liners 19 which are held together by means of metal assembly rings 20 extending through the outer edges thereof and preferably soldered, brazed or otherwise rigidly connected thereto. These liners are preferably self-enclosed by means of front strips and end plates fabricated thereto so that sealed cavities are provided therewithin.

The outer surfaces of each liner 19 should be in intimate contact with the explosive material and preferably define an angle of from 45 to 60 degrees. In the assembly of the device 13, which may take place on location at the point of well shooting, the liner assembly is slipped into the container 16 until the bottom end thereof engages the inwardly tapering bottom walls of the container, following which the unoccupied space within the container 16 is filled with explosive material preferably of the gelatin variety such, for example, as 90 or 100 percent gelatin, manufactured by E. I. Dupont de Nemours Company, Inc. After the casing 16 is thus loaded, a detonating cap 21 may be introduced into the explosive material preferably at the exact center thereof, i. e., along the longitudinal axis of the explosive column. The top of the container may now be closed by means of a cover 22 having an opening 22a therethrough through which extend the circuit conductors 21a leading to the ignition element of the cap 21.

Preferably, the opening 22a is sealed around

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the conductors 21a to exclude liquid from the container 16. After the device is thus assembled, and depending upon the size and weight thereof and also upon the depth of the well 10 into which it is to be inserted, the cable comprising the conductors 21a may be employed to lower the assembled device to the bottom of the well. Alternatively, a separate cable may be used for this purpose.

In lieu of the elongated V-shaped liners 19, oppositely directed conical liners of the character shown in Figs. 5 and 6 of the drawings may be disposed in the container 16 to provide rows of conical cavities in the explosive column 17 which extend longitudinally of the column. Preferably the conical cavity forming liners are arranged in sets of four with the liners of each set closed at their outer ends and held in assembled relationship either by means of crossed rods 24 welded to the apexes of the liners and to each other at the point of crossing in the manner shown in Fig. 5 of the drawings, or by means of a ring 25 which extends through the V-related walls of the liners and is welded to each liner in the manner shown in Fig. 6 of the drawings.

Alternatively, the cavity forming liners may take either of the forms illustrated in Figs. 7 and 8 of the drawings. As shown in Fig. 7, four conical shaped liners having their outer ends closed and their apexes joined together as by soldering, brazing or the like and extending outwardly at ninety degrees relative to each other are formed into one assembly of the proper diameter to fit within the casing 16. In the structure shown in Fig. 8 of the drawings, four closed end, steer horn-shaped liners 27 arranged in a set and having pointed ends rigidly connected together are used to form the four equiangularly spaced apart cavities in the explosive column 17.

When any one of the four liner constructions illustrated in Figs. 5, 6, 7 and 8 of the drawings is used in loading the container 16 in the manner explained above, several sets of the liners are sandwiched in between the explosive material at different depths longitudinally of the container as the loading operation proceeds. During this operation, care should be exercised to maintain the cavity liners in alignment longitudinally of the explosive column if it is desired that upon detonation of the column the explosive forces will be directionalized in the four principal directions of interest, i. e., toward the water wells 12. Preferably, however, the liners are angularly offset as the loading operation proceeds in order to provide all around directionalization of the explosive forces in the manner indicated by the arrows shown in Fig. 1 of the drawings. Aside from the details of the liner constructions, the device 13 may be formed using any one of the liner embodiments illustrated in Figs. 4 to 8, inclusive, in the exact manner explained above with reference to Figs. 3 and 4 of the drawings.

Preferably, the liners, regardless of configuration, are formed of non-sparking metal, such as brass or copper, to minimize the likelihood of inadvertent detonation of the explosive material, and have a wall thickness of the order of 0.075 inch. In lieu of assembling all components of the entire device 13 on location, the liners or liner subassemblies may, of course, be preassembled with the container 16 during manufacture. In such case, it is desirable to fabricate the edges or ends of the liners to the inner wall of the

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container in order to insure maintenance of the desired positional relationship between the cavities formed in the explosive column when the container is loaded with explosive material.

For reasons apparent from the foregoing explanation, it is desirable to employ explosive charges in the water wells 12 which, upon detonation, produce directionalization of the explosive energy generally toward the oil well 10. More specifically, the explosive forces should be directionalized within a quadrant of about thirty degrees, the bisecting line of which passes through the oil well 10. To this end, the liner arrangement of the explosive charge may be of the form illustrated in Figs. 9 and 10 of the drawings. As there shown, the container 16a, which may be identical with the container 16 shown in Fig. 3 of the drawings is filled with explosive material to form an explosive column 17a having conical cavities 18a formed therein along one side thereof and spaced longitudinally of the column. These cavities are formed by providing conical shaped liners 28 of non-sparking metal which extend transversely of the column at spaced points longitudinally thereof and are provided with rod extensions 28a at the pointed ends thereof such that they may be wedged into the container 16a. These liners may either be fixedly secured within the container 16a in the manufacture of the container assembly, or alternatively may be forced into the container during loading thereof at the point where the well shooting operation is to be carried out. Preferably they are angularly staggered in the manner indicated in Fig. 10 of the drawings, to point in the three directions indicated by the arrows radiating from each well 12 shown in Fig. 1 of the drawings so that the desired quadrantial directionalization of the explosive forces is obtained. For reasons explained below, with these liners arranged in staggered alignment longitudinally of the explosive column, the explosive forces developed upon detonation of the column are directionalized along a quadrant bisected by a vertical plane which also bisects the aligned center cavities. Accordingly, in lowering each device 14 into one of the water wells 12, care must be taken to see that the center cavities 18a of the device are pointed toward the well 10 as the device 14 is brought to rest at the bottom of the well 12 in which it is deposited. This may be accomplished by employing a gyroscopic device of the character commonly employed in oil well logging work.

After the cavitated charges or devices 13 and 14 have been deposited at the bottoms of the wells 10 and 12 with the cavities thereof properly directed toward each other in the manner explained above and after the circuit conductors extending to the detonating caps of the charges are properly connected to the detonator 15, they may be detonated together or one at a time through appropriate operation of the detonating device 15. Due to the effect of the cavities provided in the charges, the resulting explosive forces are concentrated and directionalized to produce cracking of the formation material adjacent the bottom of the well 10. Thus the cavities provided in the explosive columns of the shooting devices cause the well known Monroe effect to be realized. Specifically and considering one of the V-shaped cavities 18 in the explosive column 17 by way of example, the explosive forces first travel perpendicularly away from the wall surface of the cavity, meet and then travel in highly concentrated form radially outward from the axis of the explosive column. The major portion of

the explosive energy is thus dissipated in this jet effect which is concentrated along a planar path bisecting the angle of concavity. Thus in the four-cavity structure shown in Figs. 3 and 4 of the drawings the major portion of the explosive energy is directed outward in the four directions radiating from the longitudinal axis of the explosive column and bisecting the four cavity liners 18, i. e., toward the water wells 12. This means that the formation material adjacent the bottom of well 10 is broken up for a substantial distance away from the bottom of the well 10 along each of four paths extending toward the water wells 12. Four channels are thus effectively cut through the subsurface material for substantial distances away from the bottom of the well 10. If additional cavities are provided in the explosive column, directionalization is, of course, obtained in the other directions as well. Similarly, the directionalization of the explosive energy resulting from provision of the cavities 18a in each of the charges 14, cause the subsurface material to be penetrated a relatively great distance from the bottom of each of the holes 12 generally toward the well 10. Due to the fact only a minor portion of the explosive energy as developed by each charge 14 is expended in directions other than within the quadrant extending toward the well 10, it will be understood that the subsurface material outside of the quadrant is not cracked to any appreciable extent. This is of great importance, since it minimizes the amount of water which must be pumped into the subsurface structure to produce lifting of the oil to an elevation such that it will flow through the cracked subsurface material into the well 12 from whence it may be pumped to the surface. If desired, a mechanical buffer, in the form of an air space or rock wool surrounding all portions of each explosive column except the cavitated portion, may be used to further minimize breaking up of the subsurface material in directions other than toward the well 10. More specifically, rock wool is preferably used as the buffer or cushioning medium if the wells 12 are dry, and air is preferably used for this purpose if the wells are liquid filled at the time the described shooting steps are performed. The cushioning air columns may be easily provided around the non-cavitied sides of the charges 14 by employing charge containers having spaced walls defining an air space therebetween around the non-cavitied parts only of the charges. It will thus be understood that the present invention represents a distinct advance in the art of cracking the subsurface material adjacent the bottom of an oil well to permit water flooding of the oil-bearing structure for the purpose of lifting the oil to such an elevation as will permit its withdrawal from a well penetrating the structure.

Although the invention has been described above with particular reference to increasing the permeability of the subsurface oil-bearing structure adjacent a single well, it will be understood that it is generally applicable to oil field work. Thus, in any given field the water wells (or alternatively exhausted oil wells which are used for pumping water into the subsurface structure) may be interposed between and around the oil wells in various patterns. In such case, the particular pattern formed by the several wells should be taken into account in selecting the form of directionalization best suited to the particular situation as well as the particular orientation which should be imparted to each water

well charge. By so doing, shooting of the water wells may be advantageously used to increase fluid flow into several oil wells.

Shooting devices of the character illustrated in Fig. 3 of the drawings and equipped with cavity forming liners of the character there shown, or of one of the alternative forms shown in Figs. 5 to 8, inclusive, of the drawings, may be employed for the purpose of shooting an oil well to increase primary production. In such case, the same shooting technique is employed in so far as the construction and handling of the shooting device 13 are concerned. Since directionalization of the explosive energy along predetermined paths radiating from the axis of the explosive column is not required, cavity forming liners of the character shown in Figs. 11 and 12 of the drawings may, if desired, be used in lieu of those described above. As there shown, the cavities are formed by providing annular liners 29 of V-shaped cross section which are spaced apart vertically of the explosive column 17 to provide continuous annular cavities 18b of V-shaped cross section around the explosive column at vertically spaced points therealong. Preferably the outer surfaces of each liner define an angle of from 45 to 60 degrees. Here also, the liners 29 may be slipped into the container 16 as the loading operation proceeds. When this form of cavity is produced in the explosive column, directionalization of the explosive energy developed upon detonation of the explosive material is effective along vertically spaced horizontal planes rather than along angularly spaced vertical planes. The concentrating and directionalizing effect is, however, realized in precisely the manner described above, the end result being that a far greater degree of penetration of the subsurface formation material is obtained. With the Fig. 11 cavity arrangement, the penetration is substantially uniform in all directions radiating from the longitudinal axis of the borehole, an effect which is not objectionable and may be desirable in certain structures.

From the foregoing explanation it will be understood that the present invention affords a reliable and economical solution to the problem of shooting oil wells either for the purpose of increasing primary production or the purpose of directionally cracking the subsurface formation material to facilitate water flooding in carrying out well stripping operations, or other special techniques. Thus the invention provides for more widespread cracking of the formation out from the borehole (and thus better permeability) than do ordinary shooting methods, both for the outflow of fluid from the water wells and the inflow of fluid into the oil well. Further, the jet effect obtained by directionalizing the explosive forces precludes the possibility of uniformly compressing the walls of the borehole to render more difficult the flow of oil into the bottom of the well. Moreover, the high degree of concentration and directionalization of the explosive forces insures much greater penetration of the subsurface material per unit of explosive material used than can be obtained by conventional shooting methods. In addition, the shooting devices, regardless of the particular described embodiment thereof which may be used, are simple in the extreme and are comprised of low cost components which may easily be assembled at the point where the well shooting operation is to be carried out, and used by workmen familiar

with the ordinary tools and techniques of oil well and casing shooting.

While different embodiments of the invention have been described, it will be understood that various modifications may be made therein which are within the true spirit and scope of the invention as defined in the appended claims.

I claim:

1. The method of recovering oil from a depleted producer well, there being a plurality of intake wells spaced laterally from said producer well and extending to at least the depth of said producer well, which comprises the steps of lowering into said intake wells to points spaced laterally from the bottom of said producer well explosive charges having cavities in the sides thereof for directionalizing the explosive forces developed upon detonation of said charges, positioning said charges so that said cavities generally face the bottom of said producer well, whereby the explosive forces developed upon detonation of said charges are directed generally toward the bottom of said producer well, detonating said charges to open up fluid channels leading from said intake wells toward the bottom of said producer well, thereby to increase the permeability of the subsurface material surrounding said producer well, cushioning the explosive forces radiating from the exploding charges in all lateral directions other than generally toward the bottom of said producer well, thereby to prevent the breaking up or channelizing of the subsurface material in directions extending laterally from said intake wells away from said producer well and flooding said intake well with a pressurizing fluid which penetrates said subsurface material through said channels, thereby to facilitate the flow of oil into the bottom of said producer well.

2. The method of recovering oil from a depleted producer well, there being a plurality of intake wells spaced laterally from said producer well, which comprises lowering into said intake wells to points spaced laterally from the bottom of said producer well explosive charges having localized cavities in the sides thereof for directionalizing the explosive forces developed upon detonation of said charges, positioning said charges so that said cavities generally face the bottom of said producer well, whereby the explosive forces developed upon detonation of the charge in each

intake well are directed generally toward said producer well, lowering to the bottom of said producer well an explosive charge having cavities around the sides thereof for directionalizing the explosive forces in directions laterally of said producer well, detonating said charges to open up fluid channels leading from said intake wells toward the bottom of said producer well and other channels leading from the bottom of said producer well toward said intake wells, thereby to increase the permeability of the subsurface material between said producer well and said intake wells, cushioning the explosive forces radiating from the exploding charges of said intake wells in all lateral directions other than generally toward the bottom of said producer well, thereby to prevent the breaking up or channelizing of the subsurface material in directions extending laterally from said intake wells away from said producer well, and flooding said intake wells with a fluid which penetrates said subsurface material through said first-named channels, to facilitate the flow of oil into the bottom of said producer well through said other channels.

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