May 24, 1955 T. J. NOWAK 2,708,876

RING DETONATION PROCESS FOR INCREASING PRODUCTIVITY OF OIL WELLS

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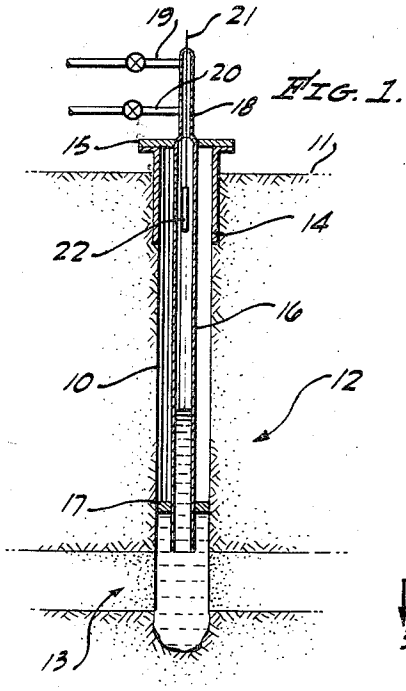


FIG. 1.

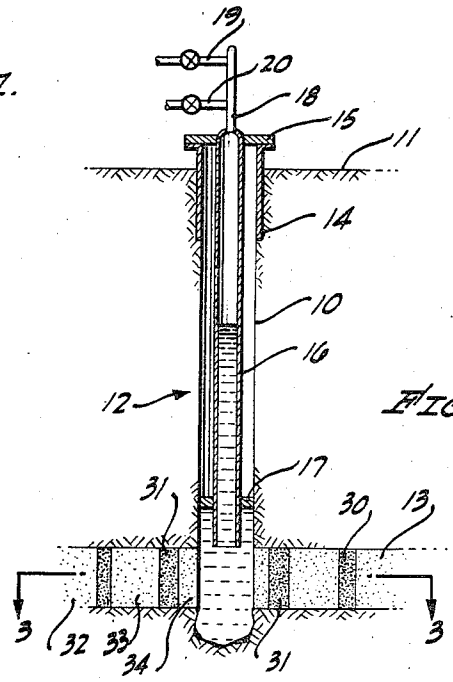


FIG. 2.

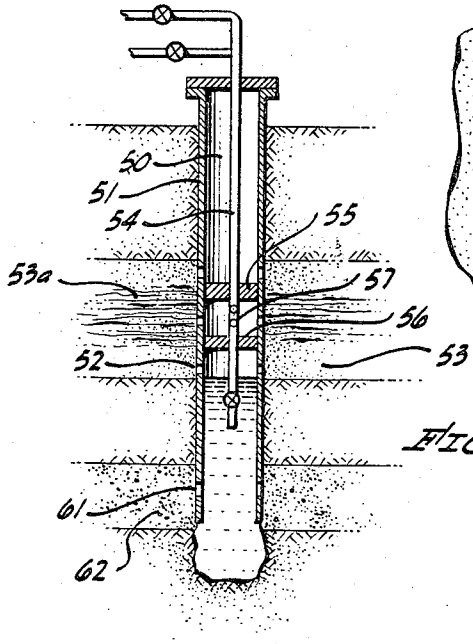


FIG. 4.

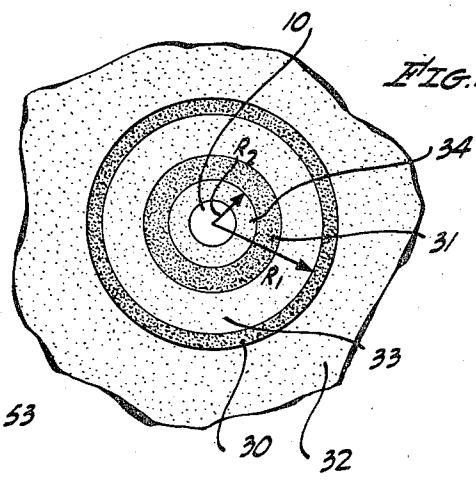


FIG. 3.

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RING DETONATION PROCESS FOR INCREASING PRODUCTIVITY OF OIL WELLS

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5 Claims. (Cl. 102—21)

This invention relates generally to methods for detonating explosives within oil-bearing formations in order to increase the flow rate and yield of oil therefrom. More particularly, this invention relates to a new method for positioning explosives within the oil-bearing formation itself wherein a maximum utilization of the explosive force is obtained with a minimum shattering and demolition of the well bore and equipment associated therewith.

The use of explosives for increasing oil production has been known for a long time and was widely practiced during the early development of oil field technology. A consistent disadvantage in the use of explosives has been the relative lack of control of the explosive force so that a considerable amount of damage to the well bore and to well bore equipment as well as extensive demolition of surrounding formations almost invariably results.

It has now been found that by a suitable placement of the explosives within the oil-bearing formation itself such disadvantages can be minimized while at the same time achieving a marked increase in the productivity of the well. The new method for the placement of explosives involves establishing a series of concentric rings of explosives about the bore hole and within the oil-bearing formation itself, each of said rings being separated from the adjacent ring or rings by a section of the formation saturated with an inert fluid.

It is an object of this invention to provide a method for detonating oil wells in order to increase the productivity wherein a series of annular rings of explosive are formed about the well and are exploded.

It is another object of this invention to improve the injection profile of injection wells in a secondary recovery operation.

It is another object of this invention to provide a method for placing explosives in annular rings about a well bore and within the oil-bearing formation.

It is another object of this invention to provide a method for detonating explosives within oil-bearing formations wherein the shattering force of the explosive is confined to relatively small portions of the formation and the cracking of the formation in a network pattern is increased.

Other objects of this invention will become apparent to those skilled in the art as the description thereof proceeds.

Briefly, this invention relates to methods for detonating explosives within oil-bearing formations and to methods for placing a liquid explosive or solutions of explosive in concentric rings about a bore hole. According to the invention, aliquots portions of the explosive and an inert liquid such as salt water, organic solvents, or the like are alternately forced into the formation, such as by hydrostatic pressure, whereupon a series of annular rings alternately comprising the explosive and the inert liquid is formed about the bore hole. The relative volumes of inert liquid and explosive are calculated to form a series of rings of known dimensions in order to control the placement of explosive within

the formation. In general such rings are so spaced that the differential radius (radial thickness) of each of the rings of inert fluid is approximately two to forty times the differential radius of any of the rings of explosive. Generally the radial thickness of the ring of inert fluid is within the range of about five to ten times the differential radius of the explosive ring. Under such distribution patterns the explosive is readily detonated from a central point in the bore hole while the shattering effect of the detonation is not excessive. Furthermore, there is obtained a good network of horizontal fissures throughout the area which permit the maximum oil production to be attained.

In the accompanying drawing which forms a part of this specification:

Figure 1 shows a cross-sectional view of an oil well which has been suitably packed for commencement of the placing of the explosive.

Figure 2 shows a cross-sectional view of the well of Figure 1 following the placement of two rings of explosive.

Figure 3 shows a cross-sectional view of the oil-bearing formation of Figure 2 and illustrates the disposition of annular rings of explosive about the bore hole.

Figure 4 shows an alternative method for placing the explosive within an oil-bearing formation wherein the well bore penetrates a plurality of oil-bearing zones and wherein only a section of one of the formations is to be shot with explosive.

Referring now to Figure 1, well bore 10 has been completed from the earth's surface 11 through miscellaneous formations 12 and oil-bearing formation 13. Well 10 has been partially cased with casing 14 which is fitted with casing head 15 and tubing 16. At some distance above oil-bearing formation 13, well 10 is fitted with packer 17 so as to isolate the annular space between tubing 16 and the wall of well 10. The formation pressure causes fluids to rise in tubing 16 somewhat above packer 17. Above casing head 15, tubing 16 is fitted with a suitable Christmas tree arrangement 18 to which are attached lines 19 and 20 and which arrangement is also adapted for the raising and lowering of cable 21. Cable 21 in turn supports container 22 within tubing 16. Container 22 is a thimble-shaped vessel supported at its upper open end and fitted with a suitable means not shown for emptying and discharging its contents by suitable manipulation of cable 21 or otherwise.

In preparing the formation for entry of the explosive, salt water or other such inert fluid is admitted to the system through line 20, for example, whence it passes downwardly by gravity through tubing 16 and increases the hydrostatic pressure on formation 13 causing it to accept a portion of the aqueous bore hole fluid. Following the entry of a small amount of water into formation 13, a liquid explosive or solution of a solid explosive is admitted to the system through line 19, for example, and caused to flow by gravity into container 22 which has been raised by cable 21 to the proximity of line 19. Following the discharge of explosive from line 19 into container 22, the container of explosive is lowered within tubing 16 by unwinding cable 21 from a suitable means not shown. After container 22 has reached a suitable lower level near the bottom of well 10 or at least below the liquid level of the column in tubing 16, the contents of container 22 are discharged by suitable manipulation of cable 21. This may, for example, be accomplished by an auxiliary cable fastened to a valve in container 22 not shown. One or several fillings of container 22 may be required for the transport of the entire amount of explosive to be employed to form the first ring. Following the disposition of the explosive at the bottom of well 10 the hydrostatic pressure on the

formation is increased such as by admitting compressed air to the system through line 20. The increased pressure causes the explosive which has collected at the bottom of the well to be forced into formation 13.

After the initial charge of explosive has been placed in the formation, additional compressed air is admitted through line 20 to increase further the hydrostatic pressure and force salt water from tubing 16 into the formation 13 which drives the explosive in a path immediately ahead of the advancing water front. Following the entry of the water into the formation the entire sequence is repeated with additional explosive being deposited in the bottom of well 10, subsequently increasing the hydrostatic pressure to force the explosive into the formation, and forcing additional water into the formation to drive the explosive ahead of it.

Referring now more particularly to Figure 2, a series of concentric or near-concentric rings of explosive are thus disposed about well bore 10. In Figure 2, zones 30 and 31 represent the two concentric rings of explosive which have been placed in the formation by the technique described above in connection with Figure 1. Zone 32 represents the inert liquid which preceded the disposition of the first ring. Zone 33 represents the inert liquid forced into the formation following the placement of ring 30 and prior to the placement of ring 31. Zone 34 represents the inert liquid forced into the formation following the placement of explosive ring 31.

Figure 3 shows the horizontal distribution of the explosive rings in a cross-section taken through plane 3—3 of Figure 2, and carries the same numerical designations as Figure 2. In Figure 3 R_1 represents the inner radius of the outer annular ring of explosive while R_2 represents the inner radius of the second ring of explosive. The volumes of explosive and inert liquid required to give suitable values of R_1 and R_2 may be determined by the method of calculation described hereinafter.

Following the disposition of the explosive, a suitable detonation charge, such as a small amount of TNT attached to a mercury fulminate cap which can be electrically detonated, is lowered through tubing 16 to a point facing formation 13 and is detonated thereafter so as to cause the explosion of the entire series of rings.

Figure 4 shows a method for detonating a "tight" section of one oil-bearing formation while leaving intact a second oil-bearing formation. In Figure 4 well 50 is fitted with casing 51 containing perforations 52 facing upper oil-bearing formation 53. Perforations 61 drain lower oil-bearing formation 62. Tubing 54 traverses the center of casing 51 and is fitted with packers 55 and 56 which are located immediately above and immediately below a low permeability section 53*a* of upper oil-bearing formation 53. Alternating slugs of explosive and inert fluid are introduced through tubing 54 and issue from ports 57 whence they flow by suitable pressure control into low permeability section 53*a* of upper oil-bearing formation 53 so as to set up a series of concentric rings therein. Where tubing 54 is chosen of suitably small diameter the explosive can be introduced into line 54 and spaced by suitable volumes of inert fluid also introduced into line 54 without necessity of lowering the explosive in a container such as was done in the use of container 22 of Figure 1.

It is evident that in Figure 4, the more permeable parts of formation 53 are packed off so that the flow of explosive is into the "tight' 'or least permeable section 53*a*. In this manner the "tight" section is broken to form a horizontal network of fissures which provide a more uniform injection profile when the well is used for water or gas injection during secondary recovery and for more uniform drainage of the formation during production.

Where the hydrostatic pressure of the formation is such that the liquid column in the bore rises to the earth surface, the explosive may be discharged directly into such liquid column whereupon the denser liquid explosive will normally fall slowly through the inert liquid to its position opposite the formation.

While nitroglycerine or other liquid explosives may readily be employed in this invention, solid explosive such as trinitrotoluene and the like may be dispersed in suitable inert solvents and also pumped into the formation. Low molecular weight alcohols, ketones, acids and the like may be employed as solvents for this purpose such as methyl alcohol, ethyl alcohol, acetone, methyl ethyl ketone, acetic acid, propionic acid, butyric acid and the like.

In spite of the advantages of placing the explosive in a series of rings, destruction of the bore hole and bore hole equipment often occurs in the absence of suitable protective measures. In the methods of the prior art the well has been packed with various liquids such as drilling mud, and more often with solids such as rocks, pebbles and the like. In practicing the methods of this invention it has been found particularly desirable to pack the bore hole with a soap-thickened mineral oil which is of suitable viscosity that it is pumpable while at the same time it has sufficient thixotropic properties to set up as a gel and absorb a large part of the shock wave generated during the explosion. In employing such soap-thickened mineral oils the conditions of the disposition of the explosion are so regulated that when zone 34 of Figure 2 has been suitably placed the entire part of the bore hole facing the formation 13, as well as the fluid column in tubing 16, will be filled with the soap-thickened mineral oil. One method for determining the location of such thickened mineral oil lies in the fact that an attempt to pump the thickened oil into the formation results in a great increase in pressure, thus indicating the placement of the thickened oil opposite formation 13.

The use of such soap-thickened oils is of special advantage and utility following the detonation in that the protective barrier is readily removable by dispersion in large volumes of mineral oil which are readily introduced into the bore hole for this purpose.

In general mineral oils may be thickened with any suitable metallic soap, particularly alkali and alkali earth stearates, oleates, palmitates, rosinates and the like. For example, I may employ various mineral oils, such as heavy gas oil, which have been thickened with aluminum stearate, lithium stearate, or the like. Furthermore, I may also thicken petroleum distillates boiling in the lubricating oil range with other soaps such as barium oleate, barium stearate, strontium stearate, lithium stearate and the like.

The soap-thickened oils which are employed as herein described preferably have a gel strength between about 3 and 6 lbs. per 100 sq. ft. when determined by the method described in "Standard Field Procedure for Testing Drilling Fluids," July 1942, 2nd edition, page 13.

The following procedure typifies practice of the invention but is not to be construed as limiting the same.

A particular limestone formation of about 20 feet in thickness and possessing a crushing strength of about 10,000 p. s. i. and having a porosity of about 10% is selected for shooting the bore hole which is about 6 inches in diameter. In this particular case about 50 barrels of salt water are forced into the formation in order to sweep the major part of the oil content away from the bore hole. About 20 barrels of nitroglycerine are placed in the bore hole under the surface of a column of water and pressure is applied to the water to force the explosive into the formation. An additional 70 barrels of salt water are forced into the formation after the entry of the explosive. Thereupon an additional 15 barrels of nitroglycerine are placed in the bottom of the bore hole and are forced into the formation, after which an additional 20 barrels of salt water are run into the formation.

A bore hole protecting composition is prepared from about 800 parts of fuel oil, 24 parts of the sodium soap of disproportionated rosin, 50 parts by weight of cal-

cium oxide and 10 parts by weight of water. The mixture is introduced into the bore hole opposite the explosive charges and fills the bore hole to a level well above such charges.

The nitroglycerine in the formation is exploded by detonating about 5 pounds of TNT in the bore hole opposite the formation. Following the detonation, light gas oil is introduced into the bore hole to disperse the thickened oil and to wash out the rock fragments in the bore hole. Following the cleaning of rock and other debris from the bore hole the well is produced in the normal manner. As a result of such treatment the oil production is markedly increased.

A simple calculation can be made to determine the thickness of an explosive ring around the well bore at any specified distance from the center of the well. It is assumed that the explosive fluid will penetrate the same evenly in all directions, spreading in a ring whose center is the well. When the "inert" fluid is injected, it will drive the explosive fluid away from the bore hole and back into the sand and the ring will diminish in thickness according to the equation:

$$T=\sqrt{D^2-r^2+d^2}-d$$

Where:

T=thickness of the explosive ring at any point,
D=distance into the sand the explosive had penetrated at the time of initial entry of the displacing inert fluid into the sand face,
r=the radius of the well bore,
d=distance from the center of the well to the inside edge of the explosive ring.

Using the foregoing method of calculation it can be determined that in the preceding example the inner radius of the outer ring of explosive R_1 is about 10 feet and the inner radius of the inner ring R_2 is about 5 feet. The thickness of the outer ring of explosive is about 0.9 feet while the thickness of the inner ring of explosive is about 1.1 feet.

It is apparent that many advantages result from the use of my method for disposing explosives about the bore hole. Thus, the shattering of the bore hole and related equipment is minimized both by the spacing of the charge and by the placement away from the center of the bore hole. The use of soap-thickened oil also protects the hole from collapse and minimizes damage to the equipment.

The use of this method creates a network of horizontal fissures about the bore hole. Without this network the oil flows according to Darcy's law for radial flow wherein the flow is proportional to the

$$ln\frac{r_1}{r_2}$$

wherein r_1 is the radius of the bore hole and r_2 is the radius of the drainage area. Under this type of flow a large pressure drop occurs within a short distance from the well which promotes gas liberation and expansion. The gas liberation decreases the permeability to oil flow by increasing the gas saturation and cooling the oil, with the result that gas flow steadily increases while oil flow decreases.

Gas production in excess of that required to drive the oil into the well bore represents wasteful depletion of reservoir energy. The cooling of the oil as a result of gas liberation and expansion increases the viscosity of the oil and in the case of paraffinic oils also causes waxy materials to precipitate in the pores, thus plugging the formation.

Where the network of fissures is established the oil flow is of the "pipe flow" type and is proportional to the length of the pipe, i. e. fissure. This type of flow does not tend toward gas locking as in the case of radial flow.

Application of the principle of the invention achieves cracking of the formation so as to form the greatest number of fissures in the least permeable part of the formation. This is of advantage in secondary recovery where it is desired to flow water or gas uniformly into the whole formation and also in production wherein it is desired to produce the formation uniformly. The method is also applicable to opening up formations which have been blocked by water swelling, mud cakes, cement plugs and the like which result during drilling and well completion operations.

The foregoing disclosure of my invention is not to be considered as limiting since many variations may be made by those skilled in the art without departing from the spirit and scope of the following claims.

I claim:

1. The method of producing an explosion within a subterranean formation penetrated by a well bore which comprises introducing into said bore a first portion of liquid explosive, applying pressure to said liquid explosive to force said explosive into said formation so as to form a circumscribing ring of explosive about the bore, forcing an inert permeative liquid into said formation, introducing a second portion of liquid explosive into said bore hole, applying pressure to said second portion of explosive to force the same into said formation, forcing an inert permeative liquid into said formation, packing the bore with a soap-thickened mineral oil composition, and detonating the rings of explosive distributed about said bore hole.

2. The method of claim 1 wherein the said inert permeative liquid is water.

3. The method for improving the productivity of an oil-bearing formation penetrated by a bore hole which comprises forcing a first portion of liquid explosive into said formation so as to form a first circumscribing ring of explosive about the bore hole, forcing an inert permeative liquid into said formation so as to form a first circumscribing ring of inert liquid about the bore hole and between said first ring of explosive and the bore, forcing a second portion of liquid explosive into said formation to form a second circumscribing ring of explosive about the bore hole between the said first circumscribing ring of inert liquid and the bore hole, forcing a second portion of inert permeative liquid into said formation so as to form a second circumscribing ring of inert liquid between said second circumscribing ring of explosive and the bore hole, filling the bore hole with a soap-thickened mineral oil composition, and detonating the rings of explosive distributed about the bore hole.

4. The method of claim 3 in which the said inert permeative liquid is water.

5. The method of claim 3 wherein the quantities of liquid explosive and inert permeative liquid are such that the radial thickness of the said first circumscribing ring of inert fluid is from about 2 to about 40 times that of the first and second circumscribing rings of liquid explosive.

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