

United States Patent

Reese

[15]

3,674,093

[45]

July 4, 1972

[54] METHOD AND APPARATUS FOR
STIMULATING THE FLOW OF OIL
WELLS[72] Inventor: Dale C. Reese, 2319 Meadow Lane,
Salina, Kans. 67401

[22] Filed: June 24, 1970

[21] Appl. No.: 49,266

[52] U.S. Cl. 166/299, 166/63, 166/308

[51] Int. Cl. E21b 43/26

[58] Field of Search. 166/299, 302, 303, 308, 57,
166/59, 63, 222; 175/14

[56] References Cited

UNITED STATES PATENTS

3,422,760	1/1969	Mohaupt.....	166/63 X
2,732,016	1/1956	MacLeod.....	166/63
1,449,420	3/1923	Kreager et al.	166/59
1,843,002	1/1932	Small	166/63 X
2,668,592	2/1954	Piros et al.	166/59 X
2,776,816	1/1957	Jackson	166/59 X

3,298,439	1/1967	Rees	166/59
3,313,234	4/1967	Mohaupt.....	166/63 X
3,339,635	9/1967	Brandon	166/59 X

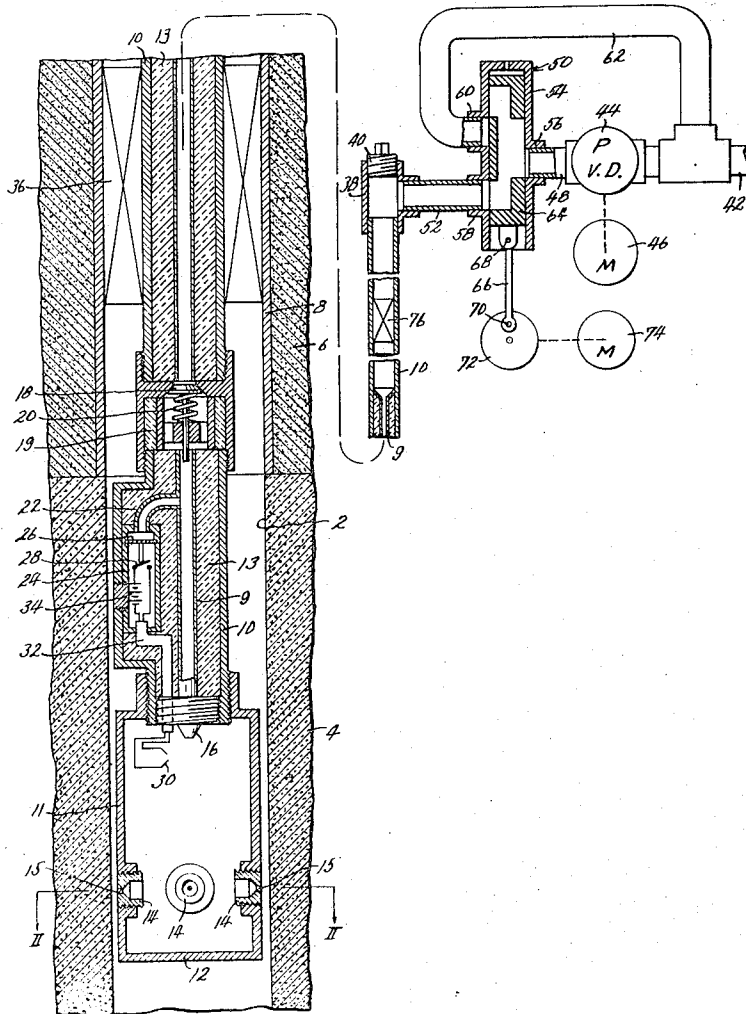
Primary Examiner—Stephen J. Novosad
Attorney—John A. Hamilton

[57]

ABSTRACT

A method for stimulating the flow of oil wells consisting of sealing off a portion of the well shaft within the oil-bearing formation of the ground, introducing a combustible fuel not requiring additional oxygen for its combustion into the sealed-off portion of the well shaft and igniting said fuel; and an apparatus capable of performing said method. The combustion produces heat, which tends to melt or burn out sludges, tars, or the like which may be clogging the oil flow passages of the formation, and also produces sudden large quantities of gaseous products of combustion, in a manner similar to a low-order explosion, which fractures the formation to form new flow passages. The flow rate of the fuel may be gradually increased, and rendered intermittent to produce a series of "explosions," whereby the zone of the oil-bearing formation treated is gradually increased.

8 Claims, 2 Drawing Figures



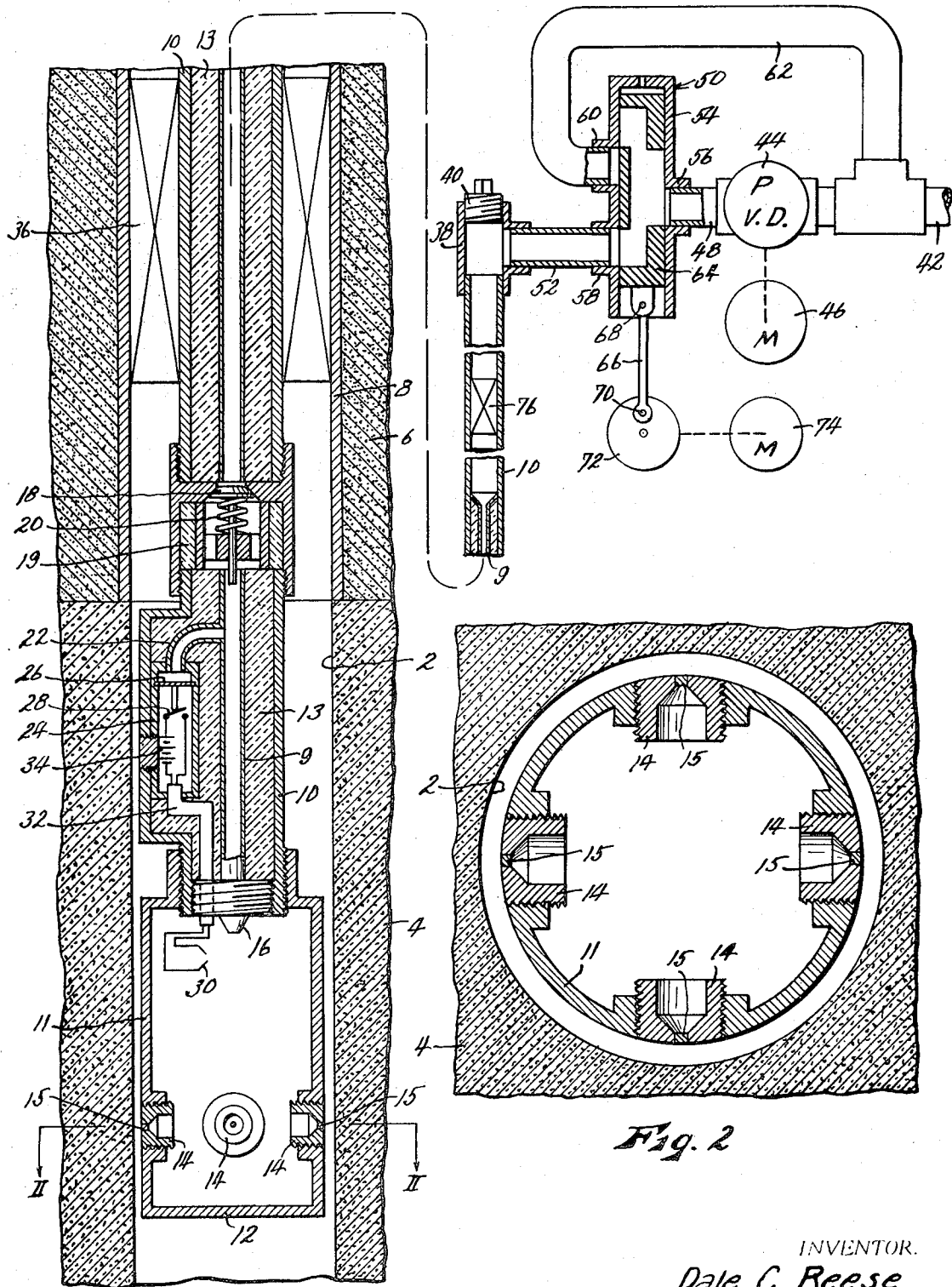


Fig. 1

Fig. 2

INVENTOR.
Dale C. Reese
BY John A. Hamilton
Attorney.

METHOD AND APPARATUS FOR STIMULATING THE FLOW OF OIL WELLS

This invention relates to new and useful improvements in oil well treating methods and apparatus, and has particular reference to methods and apparatus for reviving or improving the flow of oil wells in which the oil-bearing formation has lost its permeability to the flow of oil therethrough to the well shaft, or in which said permeability has been severely impaired, or in which the permeability is naturally low.

It is well known that oil-bearing formations may lose their permeability, so that the rate at which oil can flow therethrough to a well shaft is severely reduced, while there are still large quantities of available oil in the formation. This loss of permeability may result from many causes, the principal of which are believed to be as follows:

1. Chemical damage. Acids and other chemicals with which wells are sometimes treated, usually with the purpose of improving flow, sometimes have an eventual reverse effect, tending to combine with the oil to produce thick, gummy emulsions, acid sludges, and bacterial growths which tend to obstruct and clog the flow passages of the formation, which is usually a porous body of dolomite, limestone, or the like. This type of clogging may extend considerable distances from the well shaft, and is not particularly adapted for removal by the application of heat, since at ordinary temperatures the clogging materials may tend not to melt, but to "bake" into solid masses. They may, however, be burned or shrunk at least to some extent if the heat applied is sufficiently intense.
2. Tars and paraffins. Oil has either an asphalt or paraffin base, and as it flows through the formation it is subjected to adiabatic cooling as it passes flow restrictions. This cooling causes the base asphalt or paraffin fractions to tend to solidify and deposit on the flow passage walls, eventually restricting or cutting off the flow of oil. This condition is treatable by heat, since the asphalts and paraffins may be melted by even very slight temperature increases, but often extends to great distances from the well shaft, into zones very difficult to reach with heat.
3. Expandable clays. Many formations include bentonite or other expandable clays, which, in the presence of water or well-treating chemicals, tend to expand or swell to greater or lesser extents to close or obstruct the oil flow passages. This type of clogging also may extend to substantial distances from the well shaft, and is difficult to treat by heat, since the clay will not melt, although here again it may be burned to some extent if the heat is sufficiently intense.
4. Drilling mud. The drill bit itself, as the well is drilled of course, forms large quantities of pulverized materials, which is mixed with a drilling mud slurry of sufficient viscosity to carry the cuttings to the ground surface. When drilling is completed, the well should be thoroughly cleaned of such mud, but the operation is difficult and often performed inefficiently, so that the mud collects in the shaft, or around the well casing, and blocks the flow of oil.

Loss of flow permeability, or naturally low permeability, is most commonly treated with hydrochloric acid or other chemicals designed to dissolve portions of the formation itself, or by hydraulic fracturing of the formation, or by fracturing with liquid explosives such as nitroglycerine. None of these methods are satisfactory to any great degree. Acidizing the well too often results in the formation of acid sludges, emulsions, and bacterial growths which have an effect reverse to that desired, tending to clog flow passages despite the fact that the acids do tend to destroy part of the formation to create new passages. There is also the danger that the acid will eat through ground strata adjacent the formation and into nearby water tables, resulting in flooding of the well. Water fracturing is limited in scope due to limitations in the rate at which water or other liquids can be injected. These limitations result from pressure limitations of the well casing, and from friction losses in the casing. High explosives often cause destruction of the

casing, or even collapse thereof above the point of detonation, so that other equipment cannot thereafter be lowered through said casing. Also, high explosives may break through ground strata adjacent the formation into adjoining water tables and cause flooding of the well.

Accordingly, the principal object of the present invention is the provision of a treating method and apparatus which is efficient and effective against all of the described causes of loss of flow permeability in oil wells, while not being subject to the shortcomings and disadvantages of prior methods. The method contemplated by the present invention involves a combination, generally, of heat and fracturing methods, by the injection and combustion of a special fuel in a sealed-off portion of the well shaft within the oil-bearing formation. The fuel burns rapidly and produces great heat and large quantities of gases, creating a high pressure, but burns at a slow enough rate that at most only a low-order explosion is produced. The fuel supply rate is pulsed to provide a continuous series of these low-order explosions or sudden increases of pressure. Each pulse creates pressure sufficient to fracture a thin zone of the formation, first directly adjacent the well shaft and successively further away as the fracturing opens passages permitting access of the high pressure gas to more distant portions of the formation. The fuel supply rate may also be gradually increased to maintain the desired pressures as the zone of treatment enlarges. The fracturing is sufficiently gentle to avoid the formation of large quantities of pulverized debris, but does open new flow passages. These flow passages of course form paths for oil to reach the well shaft, but initially form passages permitting deeper penetration of the high-pressure gases and heat into the formation. The heat tends to melt or burn such clogging masses of sludges, asphalts, tars, paraffins, or expanded clays as may be capable of being melted or burned, thereby tending to open many of the old, previously clogged passages, and further increasing the flow permeability of the formation. With a modification of apparatus, the process may utilize substantially "cold" gases where desired.

A further object is the provision of an apparatus capable of performing the above method.

Other objects are simplicity and economy of both the method and the apparatus, and efficiency and dependability of operation.

With these objects in view, as well as other objects which will appear in the course of the specification, reference will be had to the accompanying drawing, wherein:

FIG. 1 is a fragmentary vertical sectional view of an oil well including an exemplary apparatus embodying the present apparatus invention, and capable of performing the present method invention, the apparatus being shown in partially schematic form, and

FIG. 2 is an enlarged sectional view taken on line II—II of FIG. 1.

Like reference numerals apply to similar parts throughout the drawings, and the numeral 2 applies to an oil well shaft, shown fragmentarily in vertical section, the oil bearing formation, which is a porous formation of dolomite, limestone, or the like, being indicated at 4 and the overlying earth strata at 6. The shaft is provided with a tubular casing 8 which extends downwardly from the ground surface, its lower end either resting on the top of formation 4, as shown, or extending downwardly into said formation. In the latter case, the portion of the casing within formation 4 is perforated for the ingress of oil. A tubular pipe stem 10 of smaller diameter than the casing is disposed within said casing, extending downwardly from the ground surface and supporting at its lower end a cylindrical combustion chamber 11 coaxial therewith, said stem being affixed to said chamber so as to communicate with the interior thereof. The lower end of said chamber is closed by an end wall 12. A series of discharge nozzle fixtures 14 are affixed in the walls of chamber 11 so as to direct jets outwardly therefrom as will appear, said nozzles being spaced equally about the periphery of said chamber and positioned to direct their jets normally to the chamber axis, or horizontally. Each

nozzle is fitted with a blow-out plug 15 which normally seals the nozzle, but which can be blown outwardly from the nozzle in response to substantial pressure within chamber 11. A very small fuel feed tube 9 extends coaxially in stem 10 from the lower end thereof to a point well above casing packer 36, as will be described, and the annular space between said tubes is filled with a suitable heat insulating material 13.

Fixed in the lower end of stem 10, in communication with fuel feed tube 9, is an injector nozzle 16 adapted to discharge a liquid fuel from said stem into chamber 11. Interconnected in stem 10 a short distance above chamber 11 is a spring-loaded check valve 18 operable to permit only downward flow of fuel through the stem, its loading spring 20 being of sufficient strength to maintain the valve closed against the pressure of the column of fuel, or fuel and water, contained in stem 10 thereabove, but to permit said valve to open when a higher pressure is applied thereto. Valve 18 is also provided with heat insulation as indicated at 19. Intermediate valve 18 and injector nozzle 16, tube 9 is interconnected by means of conduit 22 to an external switch housing 24 wherein the pressurized fuel acts against a diaphragm 26 to close an electric switch 28 to complete the operative electric circuit of an electric igniter 30 (which may be a spark gap) disposed in chamber 11 adjacent nozzle 16. The leads from switch housing 24 to chamber 11 are enclosed in a conduit 32. Electric current for the igniter may be supplied by a small, replaceable battery 34 carried in housing 24. Diaphragm 26 may be set to close switch 28 and actuate the igniter whenever injector nozzle 16 is injecting fuel into chamber 11.

Stem 10 is sealed in casing 8, above chamber 11, by means of a casing packer indicated at 36. Such packers are common and well known in the art, and therefore are not here shown in detail. The packer should be of sufficient holding power to contain the maximum pressures to be developed in the shaft during the process, as will be described, to prevent stem 10 from being blown upwardly through the casing. Fuel feed tube 11 should extend to a point above casing packer 36.

Above ground level, stem 10 is interconnected to the lower end of a T-fitting 38, the opposite or upper end of said fitting being sealed by a removable plug 40. Water is delivered to the side inlet of said T-fitting from a suitable source through pipe 42, a pump 44 having an adjustably variable delivery rate and driven by an electric motor 46, pipe 48, a pulsing valve 50, and pipe 52. Pulsing valve 50 includes a valve body 54 having an inlet 56 into which pipe 48 is connected, an outlet 58 into which pipe 52 is connected, an outlet 60 into which a by-pass conduit 62 is connected, the opposite end of said conduit being interconnected into pipe 42 ahead of pump 44, and a slide 64 mounted reciprocally in the valve body and operable as it is reciprocated to connect inlet 56 alternately with outlets 58 and 60. The valve slide is reciprocated by means of a link 66 pivoted at one end to said slide, as at 68, and pivoted at its opposite end, as at 70, to a disc 72 rotatably driven by an electric motor 74, eccentrically of the axis of rotation of said disc. Motor 74 may be of variable speed, or intermittently operated, to supply pulses of pressure to stem 10 at any desired frequency.

In operation, the liquid fuel used is preferably of the mono-fuel type, including in and of itself the supply of oxygen necessary for its combustion, so that no external source of oxygen is required. Alternatively, of course, separate conduits for fuel and a supply of oxygen to combustion chamber 11 could be used, but this would require a double plumbing system, and would be less desirable. The fuel is of a type which, while it burns at an extremely high rate when ignited, accompanied by the production of intense heat and large quantities of gas, nevertheless burns at a rate substantially less than that of a high-order explosive, so as to produce at most an explosive effect of only a low order. Various types of fuels presently utilized in rocketry, such as hydrogen peroxide or hydrazine, are suitable for use in this method and apparatus.

Since the treatment of a single well would seldom if ever require enough fuel to fill the entire length of stem 10, the

device is preferably prepared for use by removing plug 40 from the upper end of the stem, pouring in sufficient fuel for the treatment, pushing a wiper sealing plug 76 down the stem until it engages the fuel, then filling the remainder of the stem with water and reinserting plug 40. Wiper sealing plugs such as used at 76 are common and well-known in the art, and the plug is therefore not here detailed. Motors 46 and 74 are then set in operation to drive pump 44 and oscillate pulsing valve slide 64, whereby to deliver water in a series of pulses to stem 10, forcing wiper plug 76 downwardly to deliver the liquid fuel through valve 18 to ejector nozzle 16 in a corresponding series of pulses. By-pass 62 permits pump 44 to operate at a substantially constant delivery rate despite its intermittent delivery to stem 10, since during the lulls between delivery pulses to the stem, the pump output is simply by-passed back to the pump intake. Actually, in most cases, it is desirable that the pump delivery rate, or more accurately the amount of water delivered thereby during each pulse be gradually increased as the treatment progresses, for reasons to be described. Pump 44 is of a variable delivery type for this reason.

As the fuel enters combustion chamber 11 through injector nozzle 16, being expanded to mist or vapor form by said nozzle, it is ignited by igniter 30, which as previously described is actuated by the pulses of pressure in the fuel. The fuel, thus ignited, burns to create intense heat, quantities of gas and a resultant high pressure in the combustion chamber, dislodging blow-out plugs 15 and forcing the burning gases outwardly through nozzles 14 into formation 4 in the form of powerful jets. The burning rate of the fuel is sufficiently slow that combustion, accompanied by the production of more heat and more gases, is still occurring at a substantial distance away from the combustion chamber. The blow-out plugs prevent any oil or other liquid standing in the well bore, which it often does to substantial depths, from entering chamber 11 prior to combustion, which could cause destruction of the chamber due to the density of the liquid. The supplying of fuel through small tube 9 well insulated in stem 10 prevents possible pre-ignition of the fuel within said tube by the heat generated in the well bore, the safety being provided both by the insulation and also by the fact that due to the small tube diameter, the fuel passes therethrough quite rapidly.

The jets produced by nozzles 14, though they soon lose their directional force by the baffling action of the formation, have the desirable initial effect of physically shattering any drill stem "mud" which may have collected directly around the well bore. This is in addition to the effects produced by the heat and internal pressure of the gases. The jets also provide an initial horizontally radial direction to the fracturing action to be described, which may be very important if the formation is shallow and, as very commonly occurs, is disposed closely above a water table, since in that case a downward initial direction of the fracturing action might break through intervening strata into the water table to flood the well. The jets also assist in providing deep penetration of the burning gases into the formation, as the fracturing action progresses to greater distances from the well shaft. The equal angular spacing of nozzles 14 balances the reactive forces of the jets on chamber 11, so that said chamber is not battered against the walls of the formation.

As the fuel penetrates into formation 4 and burns rapidly, it produces intense heat and large quantities of gases, which due to their confinement cause a very high pressure. As previously discussed, this action is not as rapid or violent as that of a high-order explosive such as nitroglycerine, producing at most an explosion of very low order. For want of a better term, the term "burn" may be substituted for "explosion." The pressures produced should be sufficient to cause fracturing of only that portion of the formation into which the gases have directly penetrated and immediately outwardly therefrom, and this force may be adjusted by regulating the amount of fuel injected on each pulse. After each burn the pressure tends to dissipate itself through the formation, and then another fuel pulse and burn occurs, during which the expansive gases are

enabled to reach deeper into the formation through the fissures opened by the previous burn, and so on through a large number of burns until the formation has been fractured to almost any desired distance from the well shaft. Thus each successive burn operates on a larger "face" of the formation at a greater distance from the well shaft, and requires a greater amount of fuel to provide the desired fracturing pressure, while the initial burns operate only in a relatively restricted zone of the formation directly adjacent the well shaft, and require correspondingly small amounts of fuel to produce the desired pressures. It is for this reason that it is generally desirable that the fuel supply rate be gradually increased as the treatment progresses.

It is also desirable that the gas pressures generated by each fuel burn be allowed to dissipate before the next burn, in order to avoid the creation of excessive demolition of the formation and destruction of adjoining strata, which may separate the formation from water tables, and to avoid the build-up of excessive temperatures in the formation. Since the rate of pressure dissipation is determined by the permeability of the formation, which of course varies, it is desirable that the fuel pulsing rate be adjustable, either by changing the speed of motor 74 or otherwise. The entire treatment, including the amount of fuel required, its pulsing frequency and the amount of fuel delivered in each pulse, may be programmed in accordance with known characteristics of each individual well.

During the entire treatment, the fissures opened in the formation by the fracturing action of the fuel burns admits the intense heat of the expansive gases deeper and deeper into the formation. This heat tends to melt, or burn, any of sludges, tars, or paraffins, expanded clays, etc., which are capable of being melted or burned, and which have theretofore clogged original flow passages of the formation to reduce its permeability. This tends to open some of said original flow passages, and hence to further increase the permeability of the formation.

The method and apparatus just described have many advantages over previous methods and apparatus. In previous methods involving the injection of hydraulic fluid into the formation, or the circulation of acid or other chemicals, the circulation is greatly inhibited and slowed by the very loss of flow permeability they are designed to combat; while in the present method the fracturing forms fissures which not only provide new flow passages, but also provide for rapid and deep penetration of the hot gases into the formation. The present fracturing method has several advantages over earlier methods wherein a charge of high-order explosive such as nitroglycerine is lowered into the well and detonated within the formation.

First, the fracturing performed by the present method is relatively gentle as compared to that produced by a high-order explosive. The latter produces masses of fine or pulverized debris, which must be carefully, and at substantial expense, cleaned out of the well before the well can be returned to service if the treatment is to be fully effective. The present method, wherein the fracturing is accomplished by a repetitive series of small low-order explosions or "burns" at successively greater distances from the well bore, produces relatively little debris, so that the cleaning process is rendered much simpler and more economical.

Second, since the series of burns in the present process can be continued as long as desired, and since the distance of fracturing from the well shaft progressively increases, the formation can be effectively fractured to greater distances from the well shaft than is possible with a high explosive, even a heavy charge thereof.

Third, in the present method the fracturing is confined largely to the oil-bearing formation itself, not extending to any significant degree to the adjacent ground strata. This effect results from the facts that the fuel burns produce only very low-order explosions, and that the resulting expanding gases naturally tend to seek the path of least resistance, which is virtually always the oil-bearing formation itself due to its permeability.

Fourth, since the fracturing action is relatively gentle and confined largely to the formation itself, as described above, the present method involves little risk that the adjacent ground strata will break to connect the well to adjoining water reservoirs and flood the well. The danger of this occurrence when using high explosives is quite substantial, especially in areas where the oil-bearing formations are shallow, and have water tables disposed closely thereto.

It should be noted that the present method and apparatus is effective also in tapping formations which have a naturally low flow permeability. Formations frequently occur which are porous and which contain large amounts of oil in the pores thereof, but in which the pores or cells thereof are poorly joined, if at all, by interconnecting flow passages, so that oil cannot flow, or can flow only very slowly, to a well shaft. The fracturing of the present method can open these formations to obtain heretofore unavailable quantities of oil. The present method and apparatus is also effective in treating gas wells, not so much in the removal of clogging masses, but in the improvement of naturally low permeability.

In some cases, it may be possible that the fracturing action of the method is ample to produce the desired results, and that the intense heats produced by the burning of combustible fuel might not be desired. This might be the case, for example, where the characteristics of the well, or more particularly of the elements clogging the formation thereof, are such that intense heat might cause said clogging elements to tend to bake or "fire" into solid masses which would only clog the formation more severely. In such cases, chamber 11, which is in effect a "gas generator" in any event, could constitute a reactor chamber wherein gases are produced, with the necessary explosive force, by the intermixture of appropriate chemicals therein, but without substantial production of heat. The chemicals could be fed downwardly through stem 10 (in separate conduits of course) and injected into chamber 11 in the same manner as the combustible fuel already described. Chamber 11 would then become a "cold gas generator."

While I have shown and described a specific embodiment of my method and apparatus, it will be readily apparent that they are subject to many minor changes and modifications without departing from the spirit of the invention.

What I claim as new and desire to protect by Letters Patent is:

1. A method of stimulating the flow of an oil well consisting of the successive steps of:
 - a. sealing off a portion of the shaft of the well within the oil-bearing formation thereof,
 - b. creating gases within said sealed-off portion of the shaft, whereby said gases penetrate said formation, said gases being created with an explosive force of low order whereby they fracture only that portion of the oil-bearing formation at and directly adjacent the zone of the formation penetrated by said gases, and are created in a series of pulses or bursts, whereby the gases of each successive pulse are provided access to progressively more distant zones of the formation by the fracture fissures opened in the formation by the next preceding pulse, the amount of gas released in each successive pulse being progressively increased to provide the desired fracturing pressure in the larger, more distant zone of the formation penetrated thereby.
2. A method as recited in claim 1 wherein said gas pulses are spaced apart sufficiently to allow the pressure generated by each pulse to be dissipated before the next pulse occurs.
3. A method as recited in claim 1 wherein said gases are created by the successive steps of:
 - a. injecting a quantity of combustible fuel into the sealed-off portion of said well shaft, and
 - b. igniting said fuel, said fuel, and the amount thereof introduced to said shaft, being such that said gases are produced with an explosive force of low order, capable of fracturing said formation but only those portions thereof at and directly adjacent the zone of the formation penetrated by said gases, said fuel being injected in a se-

7

ries of pulses or bursts, whereby the gases generated by each successive pulse are provided access to progressively more distant zones on the formation by the fracture fissures opened in the formation by gases generated by the next preceding fuel pulse, the quantity of fuel injected in each successive pulse being progressively increased to provide gases of the desired fracturing pressure in the larger, more distant zones of the formation penetrated thereby.

4. A method as recited in claim 3 wherein the fuel pulses are spaced apart sufficiently to allow the pressure generated by combustion of each pulse to be dissipated before the next pulse occurs.

5. An apparatus for stimulating the flow of an oil well comprising:

- a. a chamber having means adapting it to be lowered through the shaft of the well into horizontally aligned relation with the oil-bearing formation of the well,
- b. means for sealing the well shaft at a point above said chamber, and

5

10

15

20

25

30

35

40

45

50

55

60

65

70

75

8

c. gas generating means carried in said chamber and operable to generate large quantities of gas under high pressure in a series of distinct pulses, and including means for adjusting the volume of gases generated in each pulse, said chamber having outlets permitting the escape of said gases from said chamber into said formation.

6. An apparatus as recited in claim 5 wherein said gas generating means includes means operable to adjust the frequency of said pulses.

7. An apparatus as recited in claim 5 wherein said gas generating means comprises:

- a. means for injecting a combustible fuel into said chamber in a series of distinct pulses,
- b. means operable to adjust the quantity of fuel injected in each pulse, and
- c. means operable to ignite each pulse of said fuel.

8. An apparatus as recited in claim 7 with the addition of means operable to adjust the frequency of said fuel pulses.

* * * * *