United States Patent

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[72] Inventors Clarence R. Fast;
Morton A. Mallinger, both of Tulsa, Okla.;
Donald J. O'Connor, Seymour, Ind.

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[73] Assignee Amoco Production Company
Tulsa, Okla.

[54] **METHOD FOR TREATMENT OF FLUID-BEARING FORMATIONS**
5 Claims, 7 Drawing Figs.

[52] U.S. Cl. 166/299, 102/21, 102/21.6
[51] Int. Cl. E21b 43/26
[50] Field of Search 166/299, 308, 63; 102/20, 21, 21.6, 99-101

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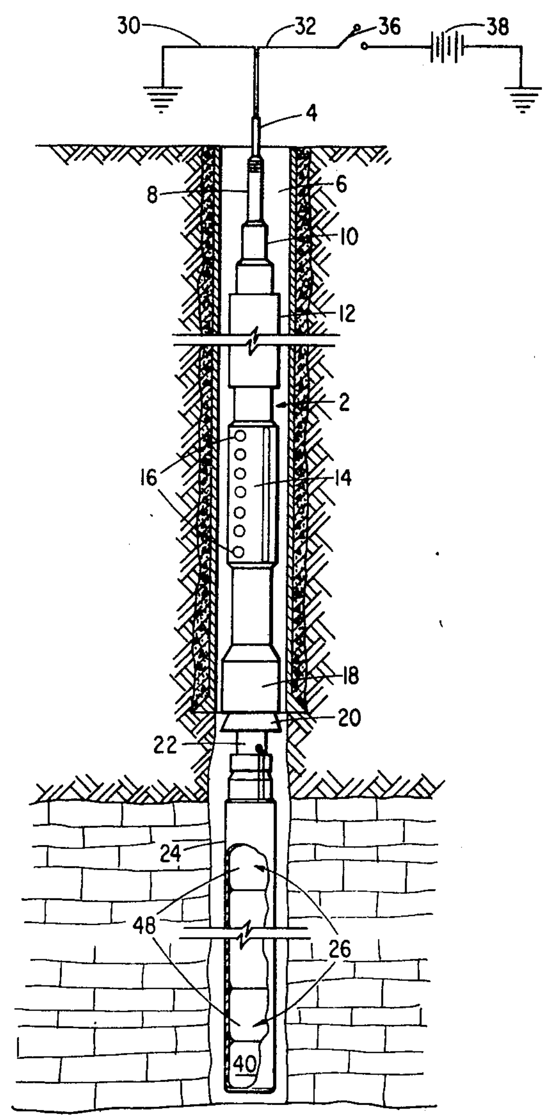
Primary Examiner—Jan A. Calvert
Attorneys—Paul F. Hawley and Arthur McIlroy

ABSTRACT: By the process of this invention, underground formations can be fractured through a series of steps comprising first building up pressure in a confined zone with a slow burning propellant sufficient to initiate the fracture. Thereafter, fast burning propellant present in the total charge is ignited to supply large volumes of gas at a pressure sufficient to extend the initiated fracture.



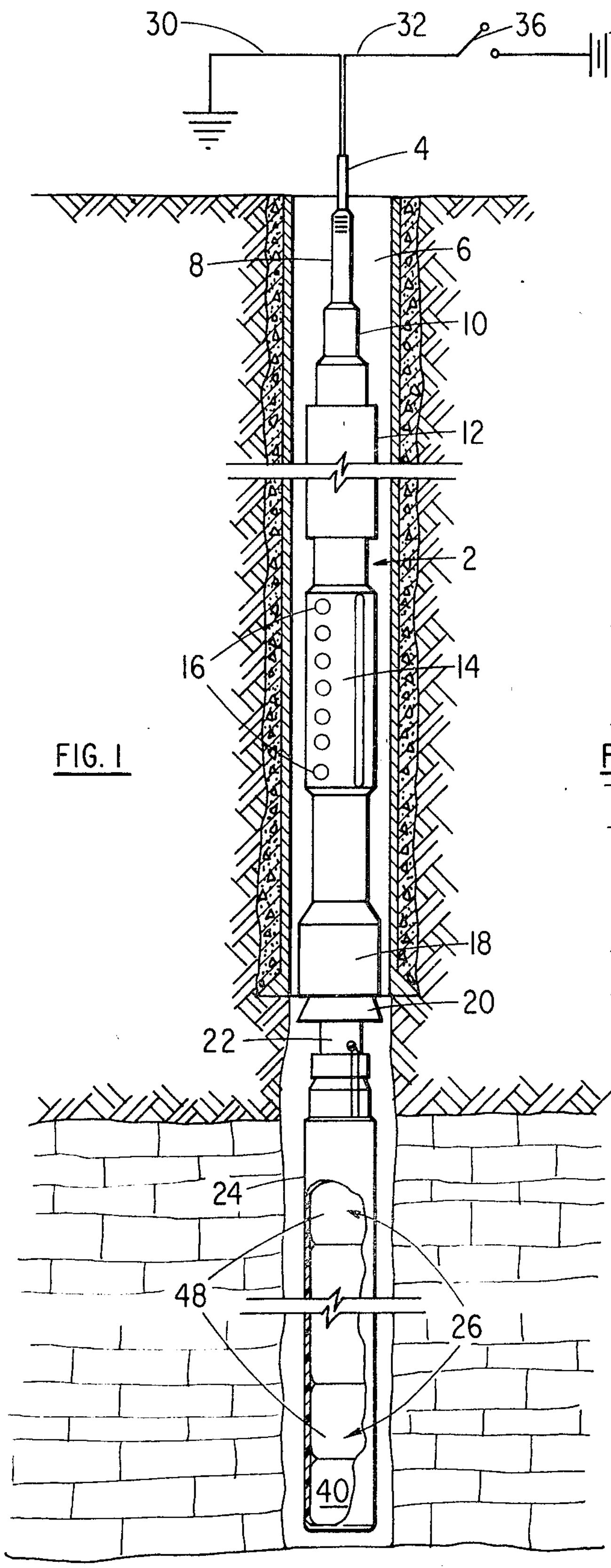


FIG. 1

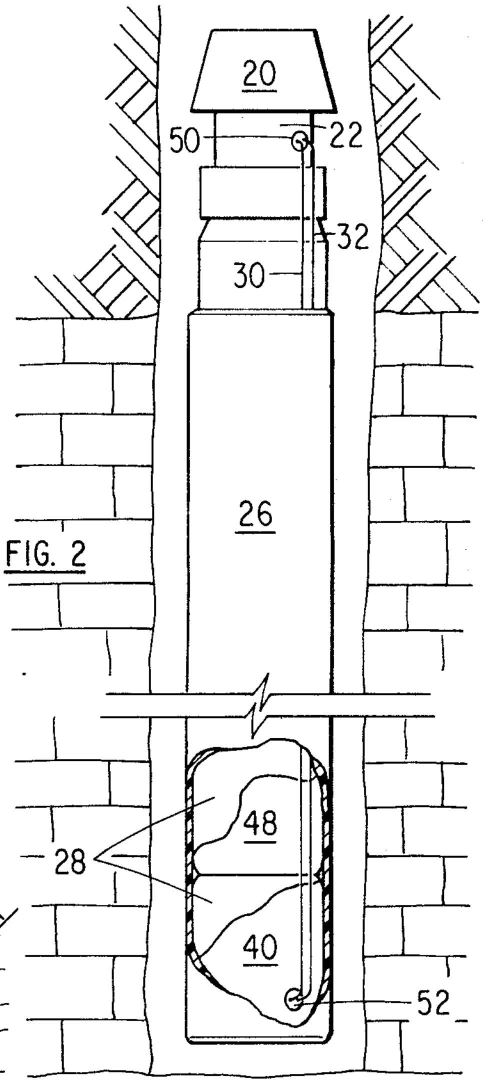


FIG. 2

DONALD J. O'CONNOR
CLARENCE R. FAST
MORTON A. MALLINGER
INVENTORS

BY Arthur McIlroy

ATTORNEY

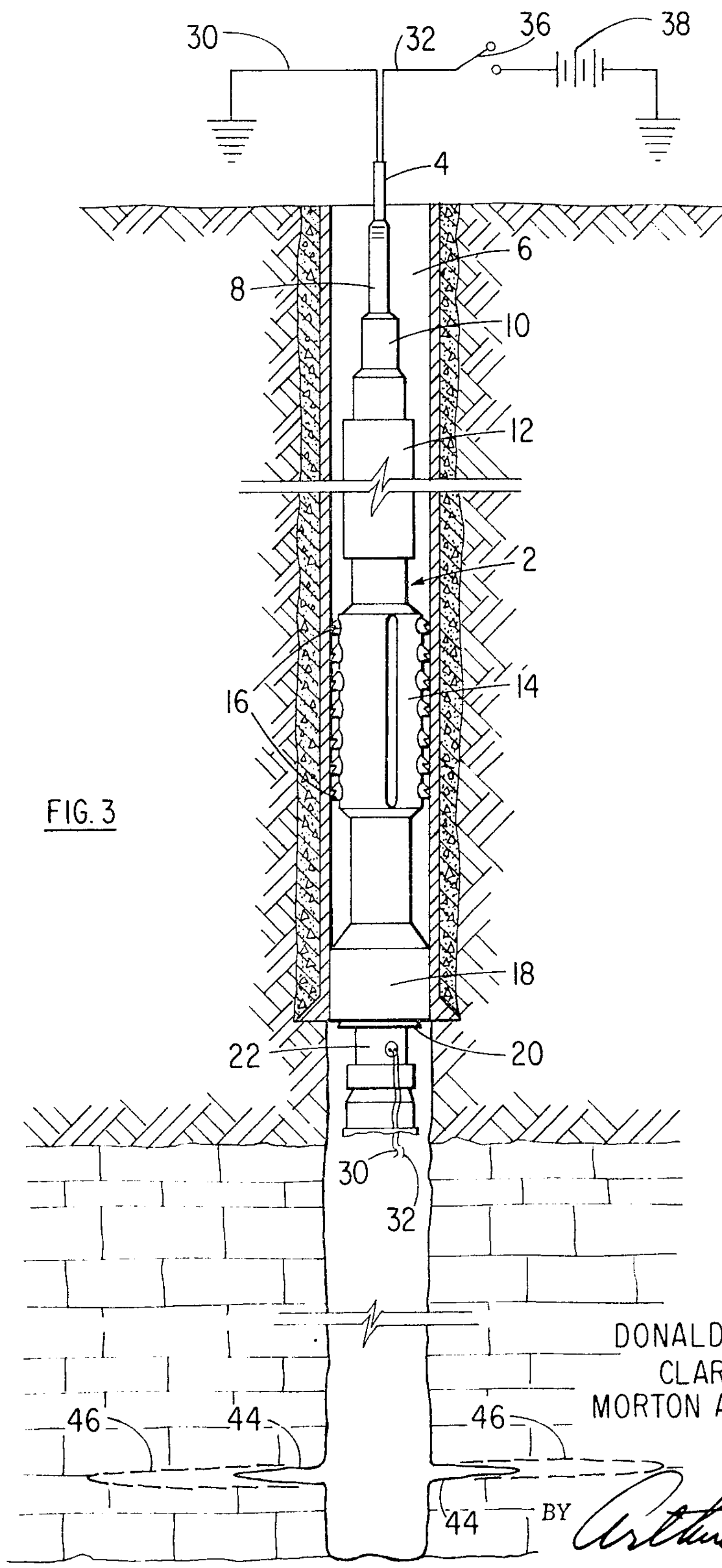


FIG. 3

DONALD J. O'CONNOR
CLARENCE R. FAST
MORTON A. MALLINGER
INVENTORS.

BY Arthur McElroy
ATTORNEY.

FIG 4

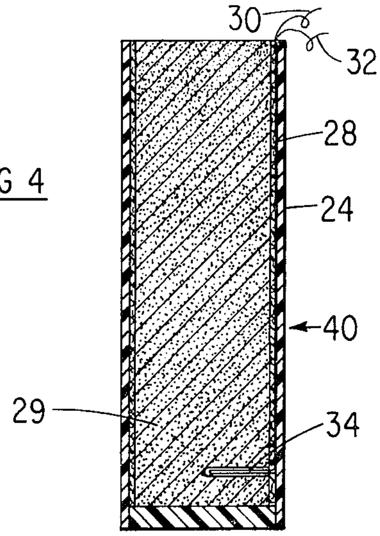


FIG. 5

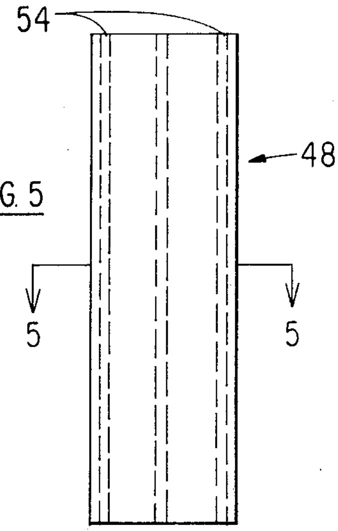


FIG. 6

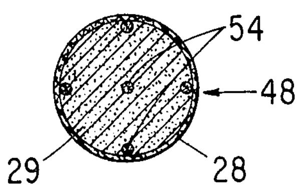
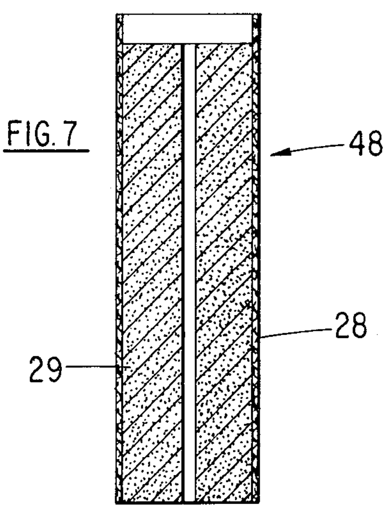


FIG. 7



DONALD J. O'CONNOR
CLARENCE R. FAST
MORTON A. MALLINGER
INVENTORS

BY [signature]

ATTORNEY

METHOD FOR TREATMENT OF FLUID-BEARING FORMATIONS

INTRODUCTION

The present invention relates to the use of propellants for the purpose of stimulating the production of fluids from certain underground formations. More particularly, it is concerned with an improved technique for using propellants under controlled conditions whereby maximum stimulation of such formations can be obtained without damage to the casing or excessive shattering of the formation as was frequently experienced with the use of nitroglycerine and similar materials. Propellants may be classified as low explosives and differ from high explosives in that the rate of energy released by autocombustion can be controlled within limits.

BACKGROUND OF THE INVENTION

In fracturing a fluid-bearing formation by use of a propellant or other high-pressure gas releasing means, care should be exercised so that the energy released is not so rapid as to approach detonation rates. If so, the effect on the formation is similar to that obtained with a high explosive such as nitroglycerine. While with the latter type of material a substantial portion of the formation around the well bore is shattered, the fractures formed usually do not extend very far away from the well and frequently have a rather small drainage area and therefore the increase in well productivity is not as great as desired.

In the previous use of propellants for the purpose of well stimulation, precautions were not taken to tailor the propellant charge to the formation conditions. For example, when burning a propellant charge in a well that had previously been fractured, the burning rate was much too slow. In some instances, the burning rate was so slow that no pressure built up during the burning operation because the gaseous products of combustion leaked off to the fracture as fast as they were generated. In a procedure of this kind the propellant is burned in a packed off zone so that fracturing pressure can be produced. In low-pressure wells the propellant charge burns at a relatively lower rate and as the pressure builds up under the packer it burns more rapidly but does not reach as high a burning rate as desired because of the character or configuration (burning area) of the charge.

BRIEF DESCRIPTION OF THE INVENTION

We have now perfected a reliable technique for fracturing a fluid-bearing formation penetrated by a well involving the use of a wire line operated casing packer and gas generating assembly. Briefly, we employ a propellant configuration that will permit slow burning of approximately one-tenth to one-fourth of the charge in the packed off zone. At this stage, enough combustion products are produced to increase pressure so that a fracture or fractures in the formation are initiated. The remainder of the propellant charge should be of such a character or configuration that it burns rapidly, e.g., 0.2 in./sec. under well conditions. Rapid burning and generation of combustion gases at high pressure thus permits extension of the fractures started by the slow burning propellant. Regulated burning of the propellant charge is accomplished by preparing the latter so that the initial portion of the charge, e.g., 20–50 pounds of a 200-pound charge, burns from the end in he same manner as a cigarette. To do this the propellant is placed in a suitable restrictor material such as a cardboard or waterproof paper cylinder that will resist ignition from hot gases along the sides of the propellant contained therein. The remaining portion of the propellant is either naturally a faster burning material or has a configuration such that it will ignite from the initial portion but will not burn from end to end as is true in the case of a cigarette. The aforesaid remaining portion is made up of several sustainer units which may have one or more holes in or near the center of the units so that after the initial igniter unit has burned, the remainder of the charges will burn very rapidly because of their increased surface area. It may be desirable to have the major or fast burning portion of the propellant in sections so that it can be readily placed in the well. In any event, these sectional joints should be resistant to the penetration of well fluids and be restricted to the penetration of hot gases so that well fluids will not enter the centrally drilled hole in the propellant and prevent rapid combustion. The propellant charge may be made up of a solid igniter and, if desired, additional slow burning, e.g., 0.05 to 0.1 inch/second, sustainer units. The other portion of the charge has some fast burning sustainer units that can ignite from the slower burning propellant sections. The fast burning units can be prepared by embedding fast burning igniter cord in the propellant, such as, for example, DuPont's Pyrocore igniter cord. This product is in the form of a small diameter continuous tubing containing an ignition composition. Its core is designed to promote ignition at the speed of detonation. By embedding such a material in the sustainer unit, instant ignition of the unit can be obtained. When the igniter cord is activated by the adjacent igniter or sustainer unit, the fast burning sustainer unit can be made to burn at as many surfaces as desired.

In setting the propellant charge either in a cased or open hole, it is generally preferred to place the charge in a relatively confined, packed-off section of the well. Thus, if the bottom of the charge is placed close, i.e., 5–10 feet from the bottom of the well, only an upper packer need be set. However, if the zone to be fractured is at an intermediate level it should be in a confined space formed by an upper packer, with the remainder of the hole being plugged back with sand, a bridge plug or other suitable means, up to a level of from about 5 or 10 feet from the base of the propellant charge. This is primarily to insure uniform and rapid burning of the major portion of the charge. If the latter is not placed near the bottom of the well, or the space immediately below the charge is not packed off or plugged back, the hot gaseous combustion products from the igniter section can travel down the well instead of moving upwardly past the outer surfaces of the sustainer units. This results in slower and nonuniform burning of the main charge. With relatively slow generation of the gases, fracturing extending pressures generally cannot be reached before such gases are dissipated out into the formation.

The composition of the propellants used in the process of our invention vary rather widely, the principal objective being to employ a charge having the burning characteristics discussed above. Typical of such propellants are the ammonium nitrate type, preferably with from about 5–10 weight percent of an asphalt binder. Usually these compositions contain ½–1 weight percent of a stabilizer such as toluene diamine and 5 or 10 weight percent of a catalyst such as Prussian blue, ammonium chromate, potassium chromate or a mixture of chromates with metal oxides or silicates.

Propellants of the type described are used in the form of cylindrical sections typically 4 inches in diameter and 36 inches long for the igniter units, and the sustainer units are preferably 18 inches in length and 4 inches in diameter. Approximately 8 pounds of propellant should be used for each linear foot of hole exposed to treatment, with a minimum of 200 pounds in the total charge for each treatment. With this size of propellant charge, about 150,000 B.t.u. of heat and 3,600 s.c.f. of gas are generated in less than one minute. A charge of this weight (200 pounds) 4 inches in diameter is about 25 feet long. The propellant charge is preferably carried in a polyvinyl chloride tube, closed at the bottom end. The assembly of propellant charge and carrier is affixed to a wire line operated casing packer-hydraulic hold down tool and lowered into the well to the desired depth. Propellant charges of the type mentioned above, when used in accordance with our invention, create fractures in the formation for a distance of 50 feet or more, and will heat the area immediately adjacent the well to cause removal of scale and spalling of the formation face in open hole wells.

BRIEF DESCRIPTION OF THE DRAWINGS AND A PREFERRED EMBODIMENT OF THE INVENTION

For a better understanding of our invention, reference is made to the following drawings wherein:

FIG. 1 is an elevational view of apparatus used in practicing our invention shown as disposed in a well;

FIG. 2 is an enlargement of the lower section of the assembly shown in FIG. 1, illustrating the wiring arrangement used to activate the flame squib which rests in the lowermost ignition unit;

FIG. 3 illustrates the apparatus of FIG. 1 after the packer and hydraulic anchor have been set, with the initial and extending fractures formed;

FIG. 4 is a sectional elevational view of a slow burning igniter unit equipped with an electric flame squib and enclosed in a plastic casing;

FIG. 5 is a sectional view of a fast burning sustainer unit equipped with igniter tubes;

FIG. 6 is a cross-sectional view of FIG. 5 taken along line 5—5; and

FIG. 7 is a sectional elevational view of another type of fast burning sustainer unit in which channels have been drilled into the propellant to increase the burning surface area.

Referring again to FIG. 1, the tool 2 is suspended on an armored cable 4 into cased well 6. The tool is lowered into the well by means of cable 4 affixed to cable head 8. Firing unit 10 containing an igniter assembly joins cable head 8 and anchor actuating propellant chamber 12. The latter contains a propellant charge varying in size depending on the depth at which the anchor and packer are to be set. To the base of propellant chamber 12 the upper end of anchor 14 is engaged. Anchor 14 is equipped with slips 16 that project out horizontally against the casing (see FIG. 3) by means of gas generated when the propellant in chamber 12 is ignited. This same charge also serves to set packer 18 through the upward movement of setting wedge 20. At the base of setting wedge 20 is an adapter sub 22 which joins wedge 20 with propellant container 24 constructed preferably of a combustible material such as plastic, for example, polyvinyl chloride or magnesium. Within container 24 is a series of propellant canisters 26 encased in a water resistant paper 28 (see FIGS. 2 and 7).

Conductor wires 30 and 32 lead to armored cable 8 and function to fire both the anchor actuating propellant and the main propellant charge, the lowermost end of which contains a flame squib 34 as shown in greater detail in FIG. 4. A suitable squib for this purpose is the type described and claimed in copending application U.S. Ser. No. 25,063, filed Apr. 2, 1970 by Clarence R. Fast et al. Electrical switch 36 is closed at ground level to introduce current from power source 38 to firing unit 10 which in turn activates the charge in anchor actuating propellant chamber 12. Simultaneously, current is introduced into flame squib 34 which serves to initiate slow burning unit 40. The anchor activating propellant is fast acting, while the propellant in canister 40 is slow burning. This permits anchor 14 and packer 18 to be set in position before propellant charge 40 burns. The latter builds up sufficient pressure in confined space 42 (see FIG 3) to initiate a fracture 44 in the formation. Pressure built up within confined zone 42 by ignition of fast burning propellant 48 is sufficient to extend the initiated fractures to a position such as that shown by dashed lines 46. If the pressure under packer 18 builds up to a higher value than that trapped in the packer, a check valve arrangement such as that described and claimed in copending application, U.S. Ser. No. 25,125, filed Apr. 2, 1970 by Clarence R. Fast et al. may be employed. This valve is located in adapter sub 22 and opens when excessive pressure builds up underneath the packer, permitting the pressure to enter the packer-anchor combination and keep the tool in a set position. After completion of the burning of the fast acting propellant, the pressure in the tool is bled off by pulling on armored cable 4 which opens a spring loaded pressure release valve. When pressure above and below packer 18 is equalized, anchor slips 16 are retracted by means of built in springs and the assembly brought to the surface.

In FIG. 2, wires 30 and 32 are brought outside of the upper portion of adapter sub 22 through an opening 50. These wires run between paper wrapping 28 and plastic carrier 24 until they reach the lowermost canister 40 which contains the slow burning propellant. Near the base of canister 40, wires 30 and 32 enter a recess 52 where they make contact with flame squib 34, as shown in FIG. 4.

FIGS. 5 and 6 illustrate an embodiment of sustainer unit 48 capable of rapid burning and building up pressure in a confined zone sufficient to extend a formation fracture after the latter has been initiated by the combustion of a slow burning propellant charge such as that referred to in FIGS. 2 and 4. Sustainer unit 48, as shown in FIG. 5, is equipped with a plurality of igniter tubes 54, the number of such tubes in each sustainer unit depending upon the speed with which it is desired for the burning process to take place.

FIG. 7 represents still another kind of rapid burning sustainer unit suitable for building up pressure rapidly and extending the initiated fracture. In this type of unit, the propellant 29 may be essentially of the same compositions as that used for the slow burning charge. However, the former is made more rapid burning by drilling holes or otherwise forming one or more channels running lengthwise through the charge so as to increase the burning surface to provide a greater surface area per unit volume than the slow burning propellant and thereby increase the propellant's burning rate.

The process of our invention will be further illustrated by the following specific examples.

EXAMPLE 1

A well in the Northwest Mallet Unit located in the Slaughter Field, West Texas, was producing from 41 feet of open hole and from 40 perforations in 5½ inch casing from a depth of 4915 to 4935 feet. In this case it was proposed to treat only the perforated section of the well since production from the open hole portion was negligible. The production tubing was pulled, the well plugged back with sand and capped with 13 feet of gypsum cement (Calseal). The tool described above was loaded with 200 pounds of catalyzed ammonium nitrate propellant, making a column about 4 inches in diameter and 25 feet long, the lowermost 3 feet of which were slow burning. When the tool had been lowered to firing depth, the packer and anchor were set at 4905 feet and the bottom of the propellant column was at 4930 feet, about 5 feet above the bottom perforation and 9 feet above the plugged back depth. The fluid level in the well was 2974 feet.

The squib was fired and about 15 minutes thereafter the tool was released and removed from the well. A sand pump was run into the well and placed in operation but only about one double handful of Calseal was recovered. No propellant or debris was found, indicating complete burning of the 200 pounds of propellant charge. Post treatment production tests taken with the sand plug in place showed a substantial increase in production. After the plug was removed, fluid recovery increased for several days, after which there was a gradual decline. The table below shows production data obtained after treatment of the well.

TABLE I

Pretreatment Production BOPD	BWPD	Test Date	Interval Treated	Post Treatment Production BOPD	BWPD
22	5	11-17	40 perforations, 2 shots per foot in 5 ½" casing		
		11-24		39	5
		11-25		38	5
		11-26			

11-30	41	10
12-7	35	9
1-7	27	7

EXAMPLE 2

The well employed in this test was located in the Turtle Bay Field, Texas, and was making 20-30 barrels of oil once each week by means of gas lift. Before treatment the well was standing full of water. The zone of interest in this well was the Lotz sand which was to be treated through twenty perforations from 6515-6525 feet. The tool was loaded with 250 pounds of catalyzed ammonium nitrate propellant, and when the packer was at a depth of 6498 feet it and the anchor were set by activation of the firing unit. Simultaneously, the flame squib in the base of the propellant column was initiated which after a ¼ second delay fired the ignition unit making up the lower 3 feet of propellant charge, the latter being approximately 3 feet off bottom. By lifting the wire line on which the tool was lowered into the well, it was unset and removed. Thereafter the well was placed back on production and produced at an average rate of 42 to 49 barrels of oil per week with negligible water.

The procedure described herein is applicable in oil and gas producing areas where formation damage or scale problems exist. This stimulation process through the application of heat and high-pressure gas to either open hole or casing perforations will result in breaking through any damaged zone or scale that may exist in perforations or in the formation around the well. This technique is also applicable in water injection wells to increase injectivity at selected intervals. The method should be useful in producing wells where short fractures are desired to increase productivity, particularly in wells damaged during drilling and completion by mud or cement filtrate and, accordingly, is to be considered as a well completion procedure.

We claim:

1. In a process for placing a fracture in an underground formation penetrated by a well by the use of a generally cylindrical elongated propellant charge, the improvement which comprises:
   - placing said charge in a confined zone opposite the portion of said formation to be fractured, said charge having a separate minor amount of a slow burning propellant and the remainder of said charge consisting essentially of fast burning propellant, said slow and fast burning propellants being in an abutting relationship,
   - igniting said slow burning propellant to build up a resultant gas pressure sufficient to initiate a fracture in said formation; and
   - thereafter igniting said fast burning propellant in said zone by use of heat generated from the combustion of said slow burning propellant whereby the gas pressure thus formed is adequate to extend said fracture a still further distance from said well.

2. The method of claim 1 wherein the slow and fast burning propellants are the same composition but the portion thereof constituting the fast burning material has a substantially greater surface area per unit volume than the slow burning propellant.

3. The method of claim 1 wherein said well is a water injection well and wherein the formation in the immediate vicinity of said well and opposite said confined zone has decreased substantially in its ability to take water at normal injection pressures.

4. In a process for stimulating the flow of fluid from an underground formation penetrated by a well, the improvement which comprises:
   - placing in a confined zone opposite said formation an elongated propellant charge, said charge being composed of a slow burning and fast burning propellants in an abutting relationship;
   - igniting said slow burning propellant in said confined zone opposite said formation to build up a resultant gas pressure sufficient to initiate a fracture in said formation;
   - igniting said fast burning propellant in said zone by use of heat generated from the combustion of said slow burning propellant whereby the gas pressure thus formed is adequate to extend said fracture a still further distance from said well; and
   - thereafter removing said fluid from said formation via said well at an increased flow.

5. In a process for stimulating the flow of fluid from an underground formation penetrated by a well, the improvement which comprises:
   - placing in a confined zone opposite said formation an elongated propellant charge, the latter being composed of a minor amount of a slow burning propellant at the lower end of said charge and the remainder being a fast burning propellant abutting against said slow burning propellant, said fast burning propellant being composed of a plurality of units abutting against one another;
   - first igniting and burning said flow burning propellant to produce combustion products in said zone in an amount and at a pressure adequate to initiate a fracture in said formation; and
   - igniting said fast burning propellant as the result of the combustion of said slow burning propellant to produce a pressure within said zone sufficient to extend the thus newly formed fraction.

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