

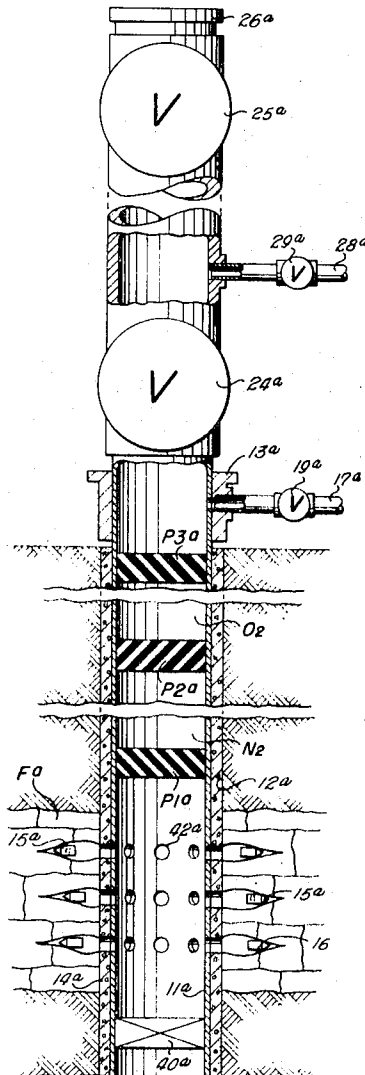
United States Patent [19]**Munson**[11] **3,727,690**[45] **Apr. 17, 1973****[54] METHOD OF FRACTURING A
NATURAL GAS BEARING EARTH
FORMATION****[76] Inventor: David M. Munson, 5128 Brookview,
Dallas, Tex. 75220****[22] Filed: Oct. 18, 1971****[21] Appl. No.: 190,099****[52] U.S. Cl.166/297, 166/299, 166/308****[51] Int. Cl.E21b 43/26****[58] Field of Search.....166/308, 297, 299****[56] References Cited****UNITED STATES PATENTS**

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**Primary Examiner—David H. Brown
Attorney—Walter J. Jagmin****[57] ABSTRACT**

A method of fracturing a natural gas bearing earth formation penetrated by a well bore by introducing a charge of oxygen into the well bore and into the producing formation in such volume as to produce an explosive mixture of natural gas-oxygen in a portion of the formation extending about and from the well bore and igniting the mixture to produce an explosion of the natural gas-oxygen mixture in such portion thereby causing fracturing of the formation. The method may also include the steps of filling the well bore with a liquid of low compressibility prior to the ignition of the natural gas-oxygen mixture present in the formation to limit or prevent damage to the well and to contain and control the explosion.

5 Claims, 4 Drawing Figures

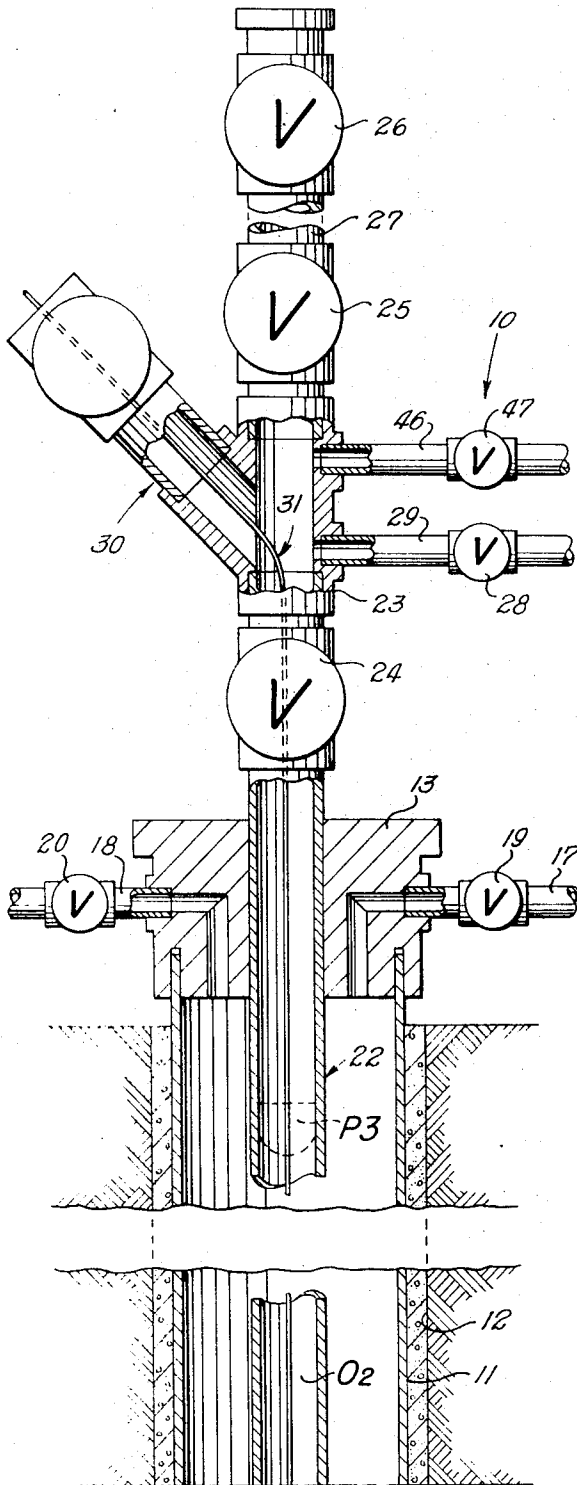


Fig. 1

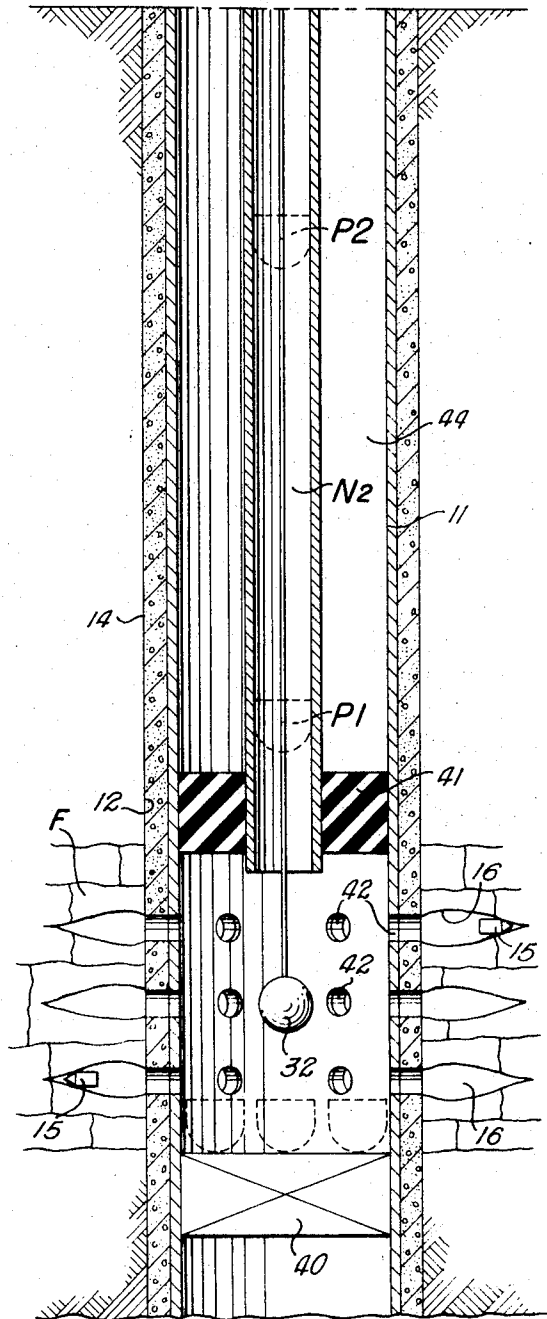


Fig. 1-A

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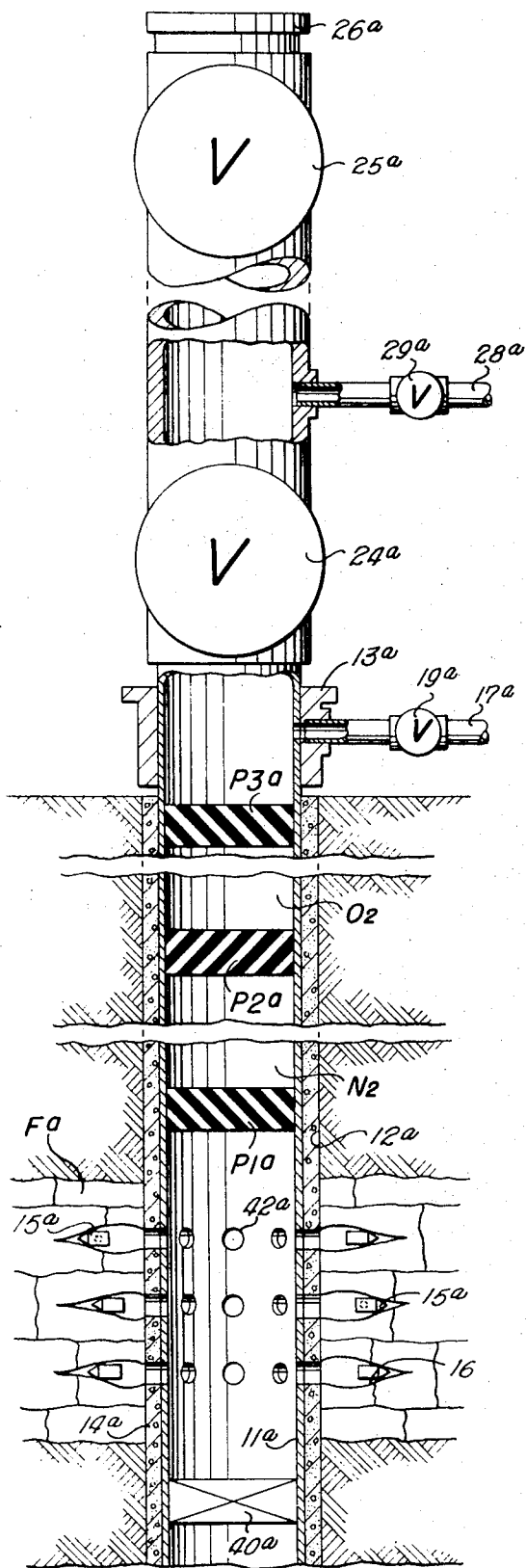


Fig. 2

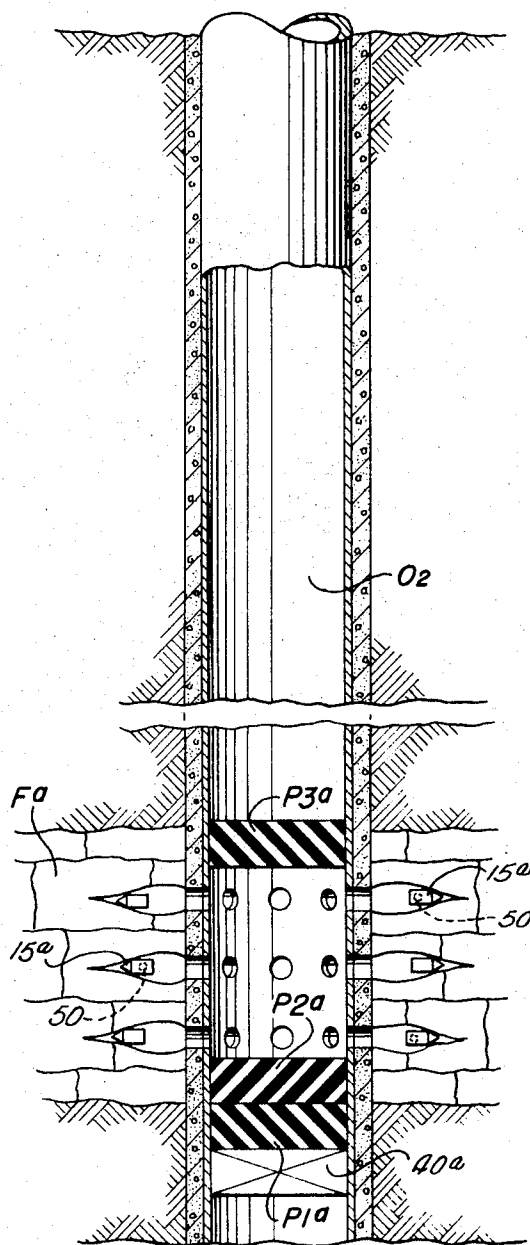


Fig. 3

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METHOD OF FRACTURING A NATURAL GAS BEARING EARTH FORMATION

This invention relates to methods for stimulating production of hydrocarbons (gas, gas condensate and oil) from an earth formation containing such hydrocarbons.

This invention is particularly applicable as a method of fracturing natural gas producing formations which are low in native permeability and thus incapable in the untreated state of producing at commercially viable rates of flow.

It is well known that stimulation of production of gas from so called "tight" gas bearing earth formations or sands may be achieved by fracturing the earth formations about the well bore which traverses the gas bearing formations by introducing various fracturing fluids (oil, water, and/or various types of emulsions) under high hydraulic pressure into the formation or by introducing a liquid or plastic explosive into the formation from the well bore and then igniting the explosive, or by exploding a nuclear device in the well bore. Each of the above methods has certain disadvantages. The hydraulic methods of fracturing a gas bearing formation are very expensive in relation to the extent of fracturing of the formation achieved, particularly in zones where the formation has low permeability. These zones may be sensitive to the fracture fluids. The water or other fracture fluids may be absorbed by clay particles or the like present in the formation decreasing the permeability thereof by a swelling action, thus reducing or limiting any beneficial effect of the hydraulic fracture treatment. The various explosive fracture methods in use are very costly particularly if the area needing to be fractured is large. Finally, the cost of nuclear devices is very high and the ecological effects related to nuclear stimulation are unknown but are of concern as to potential deleterious aspects both with regard to the safety of exploding such devices and the radioactive contamination of the earth, ground waters, and the gas to be produced, transported, and consumed by residential, industrial, and commercial users.

Accordingly, it is an object of this invention to provide a new and improved method of stimulating production of natural gas from a natural gas containing earth formation traversed by a well bore by utilizing the energy of the gas present in the formation to fracture the formation.

Another object is to provide a new and improved method for fracturing a natural gas containing earth formation traversed by a well bore to form fissures therein about the well bore which does not require the introduction of explosives or water into the producing formation.

Still another object is to provide a method of fracturing a natural gas containing earth formation by introducing a charge of oxygen, either pure oxygen or as a constituent of air, into the natural gas containing earth formation in such volume as to form with the natural gas an explosive mixture in a desired portion of the formation extending about and from the well bore and then igniting the mixture to produce an explosion in such desired portion of the formation and, if desired, repeating the process one or more times until the desired degree of fracturing of the formation has been obtained.

A further object is to provide a method, of the type described, wherein the oxygen is introduced into the formation by means of a string of tubing which opens to a blocked-off portion of the well bore at the location of the producing formation and igniting the natural gas-oxygen mixture in the blocked-off portion, with the explosion initiated in the well bore traveling outwardly through the natural gas-oxygen mixture present in the portions of the formation about the blocked-off portion.

A still further object is to provide a method, of the type described, wherein after the introduction of the oxygen into the formation to form an explosive natural gas-oxygen mixture in the formation, the mixture in the formation is ignited by ignition means introduced into the formation.

A still further object is to provide a method, of the type described, where a liquid of low compressibility is placed in the well bore above the location of the gas bearing formation to limit or prevent damage to the well during the operation of the ignition devices.

Additional objects and advantages of the invention will be readily apparent from the reading of the following description of the method of the invention, and reference to the accompanying drawings, wherein:

FIGS. 1 and 1A are a schematic sectional view of a well installation illustrating the method of the invention;

FIG. 2 is a schematic sectional view of another well installation illustrating one stage of the method of the invention; and,

FIG. 3 is a schematic sectional view of the well installation of FIG. 2 illustrating another stage of the method of the invention.

Referring now particularly to FIG. 1 of the drawings, the well installation 10, by means of which the method embodying the invention may be carried out, includes the usual casing 11 which extends through a well bore 12 and through one or more gas producing formations F. The casing is connected at its top end to the well head 13 and is cemented in the well bore in the usual manner all the way to the surface. The cement being indicated by the reference numeral 14. The casing and cement at the location of the producing formation are perforated by any suitable perforating means. Bullet or jet guns could be used. Such perforating guns fire projectiles 15 outwardly through the casing and cement and into the formation to fracture the formation and form fissures 16 in the formation which radiate outward into the formation from the casing and the well bore.

The well head has two pipes 17 and 18 which communicate with the lower end of the well head and therefore with the upper end of the well bore in the annulus between the casing and the tubing. These pipes have suitable shut-off or control valves 19 and 20, respectively, connected therein. The well head has the usual means for allowing movement of a string of tubing 22 into the well bore, means for rigidly holding the tubing against vertical movement, and means for sealing between the upper end of the string of tubing and the well head. The upper end portion of the tubing above the well head has usual surface controls connected thereto which include a lubricator 23 and longitudinally spaced master valves 24 and 25, connected at

opposite ends of the lubricator, and a safety valve 26 connected to the upper end of the extension 27 of the lubricator. A flow line 29 is connected to the lubricator between the valves 24 and 25 through which fluids or gasses may flow into or out of the tubing. The flow line 29 is provided with a wing valve 28 for controlling the flow of fluids therethrough. The safety valve 26 is of a suitable type and is held closed with a predetermined force and will open, if the valves 25 and 24 are open, when the pressure in the string of tubing below the valve 26 exceeds a predetermined value less than the bursting pressure of the tubing and fittings.

The lubricator is provided with an access conduit or means 30 through which a two conductor cable 31 may be moved into the lubricator 23. An igniter 32 is connected to the bottom ends of the two conductors. The access means 30 has suitable means for sealing between the access means and the cable 31.

In the practice of the method of the invention, with the casing 11 in place in position in the well bore 10 and cemented in place by usual cementing methods and apparatus using a heat resistant cement, the casing at the location of the natural gas bearing earth formation is perforated by usual perforating guns which fire bullets, projectiles 15, or shaped charges outwardly through the casing and the layer of cement 14 into the formation and may cause some local fracturing of the formation. The fissures 16 caused by the perforating activity radiate outwardly in the natural gas bearing formation from the casing.

The rate of flow of gas from the gas containing formation F will vary in accordance with the extent of the fracturing or fissuring of the formation, as well as with the native permeability and pressure of the formation. If it is then desired to stimulate or increase the rate of flow of gas from the formation into the casing, in accordance with the method embodying the invention, a plug 40 of any suitable type is set in the casing below the perforations.

The string of tubing 22 with an expandable packer 41 connected thereto, is lowered into the casing, the tubing is secured by usual means to the well head and the packer 41 is then set to cause a seal to exist between the lower end of the tubing and the casing immediately above the perforations 42 of the casing. Water, oil or other liquid of low compressibility is then introduced into the annulus 44 between the string of tubing and the casing above the packer 41 through the pipe 17. During this introduction of liquid into the annulus 44, the valve 20 is opened to permit escape of gasses therethrough as the annulus is filled with liquid. The annulus is filled with such quantity or column of liquid as will hold the packer 41 against upward movement upon ignition of a natural gas-oxygen mixture in the blocked-off portion of the casing between the packer 41 and the plug 40 and also as will prevent or minimize damage to the tubing upon such ignition.

A downhole displacement sealer type plug P1 is then inserted into the tubing through the lubricator valves 26, 25, and 24 in the usual manner and the valve 25 is then closed.

In order to prevent any undesired premature ignition of a natural gas-oxygen mixture in the tubing, a charge of an inert gas under pressure, such as nitrogen or carbon dioxide, may be introduced into the string of tub-

ing above the plug P1 through the flow line 28 while the valves 24 and 29 are open and the valve 25 is closed. The valves 24 and 29 are then closed, a displacement sealer type plug P2 is then inserted into the lubricator 23 through the open valve 25 to a position below the flow line 28; the valve 25 is closed and, thereafter, the valves 24 and 29 are opened to permit a predetermined volume or charge of oxygen, either pure oxygen or oxygen as a constituent of air, to be introduced into the upper end of the string of tubing above the plug P2. As these charges of inert gas and oxygen are introduced under pressure into the lubricator while the valve 24 is open, the plug P1 and thereafter the plug P2 will be moved downwardly through the tubing, their purpose being to isolate the oxygen from any natural gas in the tubing.

After the desired charge of oxygen has been introduced into the tubing, the valve 29 is closed and, if desired, if pure oxygen has been introduced, a displacement sealer type plug P3 is introduced into the upper end of the tubing in the same manner as the other plugs, and thereafter, after the valve 25 is closed, the plug P3 is moved downwardly by introducing air or an inert gas into the tubing.

As the plugs move downwardly through the tubing and finally drop through the bottom end of the tubing, the small charge of inert gas and then the charge of oxygen flows into the blocked-off portion of the casing and outwardly into the fissures 16 and pores of the formation and mixes with the formation gas to form a natural gas-oxygen mixture both in the blocked-off portion of the casing and in the formation about the bore hole.

The cable 31 with the igniter 32 is lowered into the tubing immediately behind the plug P3 through the access means 30. After a predetermined period of time of sufficient duration for the oxygen to mix with the formation gas, the igniter 32 is operated to produce either a spark or a series of sparks, if the igniter is of the spark plug type, or heat an exposed wire, if the igniter is of the hot wire type, to a temperature sufficiently high to cause ignition and explosion of the natural gas-oxygen mixture.

A mixture of natural gas and oxygen is explosive within a narrow range of the two constituents at a normal atmospheric temperature and pressure. As pressure increases, the range of explosive mixture percentage widens greatly. Also, as the temperature of the mixture increases, the range of explosive mixture percentages widens significantly. At the pressures encountered in typical natural gas reservoirs (roughly the hydrostatic head of water corresponding to the depth of the formation), the oxygen-natural gas mixture that would be an explosive mixture is a very wide range of the two constituent percentages. The desired ratio of natural gas to oxygen in the explosive range may easily ascertained by calculation. Upon the operation of the igniter 32, the natural gas-oxygen mixture in the blocked-off portion of the casing explodes and the explosion progresses outwardly into the fissures 16 as the natural gas-oxygen mixture therein combusts, thus causing fracturing of the formation and enlargement of the fissures.

If it is found that the first explosion of the natural gas-oxygen mixture does not stimulate the flow of natu-

ral gas to the desired degree, the above described procedure may be repeated to fracture further the formation and the succeeding explosions will effect a greater fracturing of the formation because a greater volume of natural gas-oxygen mixture will be present in the enlarged fissures of the previously fractured formation. In actual implementation of this invention it is expected that in some cases many cycles of the explosive sequence would be conducted. The limiting factor would be the large volumes of natural gas and reservoir opened after several explosions and the capability of injecting sufficient volumes of oxygen to create an explosive mixture at that particular formation pressure and temperature.

After the desired extent of fracturing has been achieved, the gas may be produced through the tubing 22.

At the time of the explosion of the gas-oxygen mixture in the blocked-off portion of the casing, an upward pressure will of course be exerted on the tubing and on the air or oxygen present therein. As the cross-sectional area of the downwardly facing surfaces of the tubing exposed to the pressure in the blocked-off portion of the casing is quite small and the tubing is rigidly held by the packer, the tubing will not move. The liquid in the annulus 44 will prevent lateral rupture of the tubing above the packer and the safety valve 26 will open if the pressure in the tubing rises above a predetermined safety value.

A vent conduit 46, provided with a safety valve 47, may be connected to the lubricator, the safety valve 47 opening when the pressure in the lubricator exceeds a predetermined value. The vent conduit and valve 47 are provided to allow escape of gasses and prevent excessive pressures and damage in the event of any premature ignition of gas and oxygen in the casing or tubing while the lubricator valve 25 is closed. The safety valves 26 and 46 are of a suitable type, the areas of their orifices being greater than the area of the interior of the pipe in which they are connected.

The explosion in the blocked-off portion of the casing will exert a radially outwardly acting pressure or force on the casing that may enlarge the perforations in the casing and any additional opening created therein will merely provide further means for flow of natural gas into the tubing.

If pure oxygen is used in the method, the pipes, valves and tubing through with the oxygen is moved must be of proper type for oxygen service. In addition, any lubricants used must be of a non-combustible type, such as silicone greases approved for oxygen service.

It will now be apparent that the above described method of fracturing a gas producing formation utilizes the energy present in the formation gas to produce the formation fracturing force and that the method may be carried out by use of conventional well tools well known to those skilled in the art.

Referring now particularly to FIGS. 2 and 3 of the drawings, the well installation 10a by means of which the method of the invention may also be performed is similar to the well installation 10 and, accordingly, the elements of the installation 10 have been provided with the same reference numeral, to which the subscript a has been added, as the corresponding elements of the installation 10.

The installation 10a differs from the installation 10 principally in the method of ignition of the explosive natural gas-oxygen mixture and the fact that tubing is not used to inject the oxygen into the formation. The casing and valves are cleaned for oxygen service.

The projectiles 15a have time delay detonators or igniters 50, which may be of the type used in ordnance projectiles, which detonate a predetermined period of time after they have been fired from the perforating gun.

In this case, after the casing plug 40a is anchored below the producing formation, first the casing displacement sealer type plug P1a is introduced into the lubricator 23a through the valve 25a, the valve 25a is closed, the valve 24a is opened and a charge of inert gas under pressure is introduced through the flow line 28a into the lubricator and then into the upper end of the casing, the plug P1a, which engages the casing in a manner which forms a separation between gas above and below it, moving downward through the casing due to the downward force exerted thereon by the charge of inert gas.

Thereafter, the valves 24a and 29a are closed, the valve 25a is opened and a second displacement sealer type plug P2 is inserted into the lubricator and oxygen, either pure oxygen or as a constituent of air, is introduced through the flow line 28a into the lubricator and flows therethrough into the casing moving the plug P2a, and also the plug P1a, downwardly through the casing. Finally, after the desired volume or charge of oxygen has been introduced, the valves 29a and 24a are closed, the valve 25a is opened and a displacement sealer type plug P3a is inserted into the lubricator to a position below the flow line 28a. The valve 25a is then closed, the valve 24a is opened and water, oil, or other fluid of low compressibility is introduced through the flow line 28a thus causing the plug P3a to move downward forcing the oxygen downward and into the formation as the plugs move below the perforations. At this time the plug P3a assumes the position illustrated in FIG. 3 and may be latched or locked by suitable means in a suitable landing nipple of the casing or a casing coupling collar. Alternately, a bridge plug could be connected to the bottom end of a string of tubing, closed at its lower end, which bridge plug would be latched to the casing above the perforations to close the casing thereat and the casing above the bridge plug would be filled with liquid. These steps of the method are performed within the time delay of the detonators 50 of the projectiles.

When the detonators are activated, they ignite the natural gas-oxygen mixture in the fissures and pores of the formation in an area surrounding the well bore and the explosion of the mixture fractures the formation.

The resistance provided by the head of fluid above plug P3a would limit the damage to the casing from the force of the explosion above the productive formation. The explosion occurs in the areas of the formation lying outwardly of the well bore.

After the explosion, the liquid may be swabbed out of the casing, and the plugs recovered by suitable wire line well tools or other means, and the oxygen fracture treatment repeated until the desired degree of fracturing has been obtained.

While two particular means for igniting the natural gas-oxygen mixture have been desired, it will be apparent that other means may be used for this purpose. For example, small temperature responsive igniters could be introduced with the oxygen and would move through the perforations 42a of the casing into the fissures and, because the temperature in the formation at depth is higher than at the surface, as the temperature of the igniters rises with time toward the formation temperature, the igniters eventually operating or igniting. The igniters would, of course, be provided with such amount of heat insulation as to delay this ignition or operation thereof for a suitable period of time after their introduction into the fissures of the formation. The ignition of the igniters could also be electrically or radio triggered. The time delay ignition system could be used on the tubing method of oxygen injection also.

If desired, such temperature or pressure responsive igniters could be used instead of the igniter 32 of the well installation illustrated in FIGS. 1 and 1A and would be dropped tyrough the tubing through behind the plug P3.

This second method could also be used in "open hole completion" well installations where the casing is set on top of a potential natural gas bearing earth formation and cemented. Then the formation is drilled into or through the air or special muds or drilling techniques to avoid formation damage from water contact.

The volume or charge of oxygen necessary to be forced into the formation to provide an explosive natural gas-oxygen mixture in a portion of the area adjacent to the bore hole, and the period of time during which the mixture is explosive, can be calculated by those skilled in the art since the porosity and permeability of the formation and rate of diffusion of the oxygen and natural gas therethrough are estimatable values.

The foregoing description of the invention is ex-

planatory only and changes in the method described may be made by those skilled in the art, within the scope of the appended claims, without departing from the spirit of the invention.

What is claimed and desired to be secured by Letters Patent is:

1. A method of fracturing a natural gas bearing earth formation in fluid communication with a well bore including: introducing into the formation through the well bore a charge of oxygen to form an explosive natural gas-oxygen mixture in a portion of the formation at the well bore; and igniting the mixture causing an explosion which fractures the formation.

2. The method of claim 1, wherein the method includes the steps of filling a portion of the well bore with liquid to confine the effects of the explosion of the mixture to the formation.

3. A method of fracturing a natural gas bearing earth formation traversed by a well bore having a casing cemented therein including: perforating the casing at the location of the natural gas bearing formation; closing the casing below the perforatons; introducing a charge of oxygen from the surface and through the casing and its perforations into the bearing formation to form an explosive natural gas-oxygen mixture in a portion of the formation about the well bore; and igniting the mixture in the formation.

4. The method of claim 3, and the additional step of lowering an inner flow conductor into the casing to the location of the perforations and closing the annulus between the inner flow conductor and the casing, the oxygen being introduced into the formation through the inner flow conductor.

5. The method of claim 4, and introducing a low compressibility liquid into the annulus prior to the ignition of the mixture.

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