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METHOD AND APPARATUS FOR WELL FLOW STIMULATION

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ABSTRACT OF THE DISCLOSURE

Method and apparatus for increasing the productivity of an oil or gas well wherein the apparatus has a liquid containing a propping agent disposed in a collapsible container located between opposed compressing members. The compressing members are arranged to be propelled relatively together to collapse the container thereby forcing the liquid and propping agent into the adjacent earth formation.

This invention relates to methods and apparatus for stimulating or improving the flow rate of an oil or gas well, and more particularly relates to improved methods and apparatus for improving the flow rate of oil and gas from a highly compacted earth formation.

It is now well known that oil and gas is found in subsurface earth formations or strata, and that boreholes are drilled into these formations for the purpose of capturing the oil and gas. It is also well known that after a borehole has been drilled to its intended depth, it is common practice to insert a steel casing or liner into the borehole along its entire length, and thereafter to insert cement in the annulus of the cased borehole along the face of the earth formation which contains the oil or gas fluids sought to be captured. Thereafter, the casing and cement are punctured or "perforated" in one or more spots adjacent the formation of interest, in order to permit fluid in the formation to flow into the casing and thence to the surface of the earth.

What is not so well known is that oil and gas is not usually situated in the earth in the same way that water is found. Whereas water is usually found in running streams or in subsurface pools, oil and gas is usually trapped in the tiny cavities provided by the individual sand grains of the earth or rock formation. In other words, the earth or rock is usually saturated with the oil or gas, and thus the oil and gas can flow through the earth and into the borehole only at a rate which is dependent upon the size and degree of inter-communication of these tiny cavities. Clearly then, if the earth formation is primarily composed of relatively loosely compacted material such as sandstone, any fluids trapped therein will flow relatively freely through the formation. On the other hand, a hard limestone material may be saturated with oil, but the oil may not flow hardly at all through the formation unless the flow rate is improved in some manner.

It is true that, when the casing and cement is perforated, the bullet or perforating jet functions to cut or bore a hole or channel through the casing and cement and also into the formation. Furthermore, it is known that relatively compact or hard formation substances will tend to be cracked in the vicinity of these channels as a result of this perforation, and that these cracks tend to provide avenues of escape for the oil. In other words, the impact of the bullet cutting its way into the formation will also produce small cracks in the formation rock around the channel, and oil may flow more easily and quickly through these cracks than through the pores of the rock.

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It will be apparent that cracks produced by the penetrating bullet or jet will be relatively fine, and it will also be apparent that the weight of the earth will tend to close these cracks after they have been produced. Accordingly, methods and means for reopening these cracks have been developed which involve pumping a liquid containing a "propping agent" into the well at a pressure such that the pressurized liquid tends to expand these cracks. The "propping agent" is a suitable granulated material of preselected grain size, such as sand or ground nutshells, which enters these expanded cracks and tends to "prop" them open after the pressure has been removed from the liquid.

The foregoing technique is often successful, and therefore has been widely used by the oil and gas industry. However, it is also often unsuccessful because the pressure is developed by pumps at the earth's surface, and because of the pressure losses occurring between the pumps and the location where the hydraulic fracturing is desired which may be several thousand feet below the surface. Thus, there is often insufficient force available to re-open the cracks in a formation wherein the opposing formation pressure is very great. This situation is especially apparent where the formation to be treated is relatively deep, since the formation pressure is usually much greater in the deeper formations.

These disadvantages are overcome with the present invention, and novel methods and apparatus are provided which develop an expanding back-pressure in situ which is much greater in magnitude than that provided by surface-located pumps.

Accordingly, it is an object of the present invention to provide novel methods and apparatus to improve fluid flow from a subsurface earth formation penetrated by a cased borehole.

It is also an object of the present invention to provide novel methods and apparatus for producing a momentary pressure in a cased borehole adjacent a preselected earth formation.

It is also an object of the present invention to provide novel methods and apparatus for producing a momentary pressure in a cased borehole adjacent a preselected earth formation, and to drive a propping agent into cracks in said earth formation which may be created or expanded momentarily by said momentary pressure.

It is a specific object of the present invention to provide a novel method of increasing the rate of fluid flow from a fluid-containing earth formation penetrated by a borehole, said method comprising suspending a quantity of liquid in said borehole adjacent said formation, and simultaneously producing substantially equal gas pressures above and below said liquid in said borehole to urge said liquid against said formation.

It is also a specific object of the present invention to provide novel apparatus for stimulating fluid flow from a subsurface earth formation traversed by a borehole, said apparatus comprising a collapsible container means, a quantity of liquid and particles of propping agent disposed in said collapsible container means, first compressing means mounted above said container means for compressing said liquid and propping agent downward in said borehole, second compressing means mounted below said container means for compressing said liquid and propping agent upward in said borehole, and actuating means for simultaneously energizing said first and second compressing means.

These and other objects of the present invention will be

apparent from the following detailed description, wherein reference is made to the accompanying drawing.

In the drawing:

FIGURE 1 is a pictorial representation in cross section of a cased and perforated borehole showing how the region around the perforation in the earth has been cracked by the penetrating bullet.

FIGURE 2 is a pictorial representation in cross section of apparatus for improving fluid flow from a formation such as that depicted in FIGURE 1.

As will hereinafter be apparent, the advantages of the present invention are preferably obtained with means and method for producing a sudden localized expansion of liquid, at a point in the perforated casing adjacent the formation of interest, in order to momentarily force open the formation cracks. The liquid preferably contains a suitable propping agent, and when the liquid penetrates the perforations and forces open the formation cracks, the propping agent is necessarily forced into the cracks.

As will also herein after be apparent, the pressure is preferably applied to the liquid by means of explosively-actuated pistons which drive together to provide the compressive force sought to be obtained. Since these pistons are explosively driven together, the compressive force is very great in magnitude though only momentary in duration. Nevertheless, only a momentary compression is sufficient to open the cracks and to inject the propping agent into them. When the compressive force disappears, the formation pressure tends to expel the propping agent from the formation cracks as well as to shut them. However, the cracks will tend to close very fast, and therefore a substantial number of particles of propping agent will be trapped in the cracks and will tend to hold them open after the compressive force in the borehole has disappeared.

Referring now to FIGURE 1, there may be seen apparatus A, which will be described in detail hereinafter, located in a cross sectional view of a section of a cased and perforated oil well B, and showing the borehole wall 2, a typical well casing 4, and cement 6 between the borehole wall 2 and casing 4 to seal off the face of the oil-bearing formation 8. As may also be seen, the casing 4 has been punctured at a plurality of points, and thus there are several perforations 10 which extend through the casing 4, cement 6, and well into the formation 8. Various fine cracks 12 may be seen in the formation 8 which communicate with the perforations 10, and which tend to provide escape routes by which oil or other fluids in the formation 8 may flow into the casing 4.

It will be apparent that the weight of the earth above the formation 8 is a significant factor in keeping the cracks 12 squeezed shut, and in producing the formation pressure which tends to force any fluids in the formation 8 into the casing 4 by way of the perforations 10. It will also be apparent that if an opposing pressure is created in the casing 4 which will extend into the formation 8 by way of the perforations 10, this opposing pressure will tend to open up the cracks 12 to provide a better avenue of escape for any fluids which may be trapped throughout the formation 8.

Referring now to FIGURE 2, there may be seen a pictorial representation in cross section of apparatus A designed to create a momentary hydraulic pressure in the casing 4 which will momentarily widen and probably even extend the cracks 12 in the formation 8, and which will inject a propping agent into these cracks 12 during the instant when they are forced open. In particular, the apparatus A includes an upper gun 20 containing an upper propelling charge 22 of explosive, a lower gun 24 containing a lower charge 26 of explosive, and a hollow strength member 28 having its upper end 30 threadedly connected with the breech block of the upper gun 20 and its lower end 32 threadedly connected with the breech block of the lower gun 24.

As may be seen in FIGURE 1, the apparatus A is in-

serted into the casing 4 and lowered to a depth adjacent the perforations 10 in the formation 8 by means of a standard well cable 33. Accordingly and as shown clearly in FIG. 2, the upper gun 20 is preferably provided with a threaded end 21, which will interconnect with a standard cable head 35 (see FIG. 1), and will preferably include an aperture 23 through which one or more electrical conductors (not depicted) may be inserted so as to connect with an upper igniter 34 and a lower igniter 36. The conductor which connects with the lower igniter 36 may, of course, be located in the channel 38 inside the hollow strength member 28.

As may further be seen in FIGURE 2, the upper and lower guns 20 and 24 are essentially hollow tubes each having a closed end functioning as the "breech block," and each having an open end functioning as the "muzzle." As hereinbefore stated, the upper end 21 of the upper gun 20 contains an aperture 23 and is therefore not actually closed until it is attached to the cable head 35. However, the upper end 30 of the strength member 28 functions to block off escape of gas through the aperture 23, when the upper propelling charge 22 is ignited by the upper igniter 34.

The upper gun 20 is loaded with a hollow projectile 40 which is slideably mounted on the strength member 28 as well as being slideably inserted in the upper gun 20 so as to be downwardly ejected therefrom by ignition of the upper propelling charge 22. An O-ring 42 is preferably disposed on the outside of the upper end of the upper projectile 40 so as to prevent gas from escaping between the upper gun 20 and the upper projectile 40, and another O-ring 44 is preferably mounted on the inside of the lower flange or piston end 45 of the upper projectile 40 to prevent escape of gas along the strength member 28.

The lower gun 24 is loaded with another hollow projectile 50, which is identical to the upper projectile 40, and which includes O-rings 52 and 54 which function in the manner hereinbefore explained with respect to O-rings 42 and 44. Both flanges or pistons 45 and 55 have flexible or elastic gaskets 46 and 56 of rubber or neoprene mounted on their facing surfaces, and these gaskets 46 and 56 each have raised lips 48 and 58 at their outer edges so as to provide a better seal between the outer edges of the gaskets 46 and 56 and the inner surface of the casing 4. Accordingly, gaskets 46 and 56 are preferably approximately the same size as the inside area of the casing 4, and lips 48 and 58 therefore tend to expand outwardly in the manner of tubing packers when the two projectiles 20 and 24 are driven together.

A bag-like container 59, which is preferably composed of some thin, flexible substance such as a light metal or plastic, is disposed about the strength member 28 and between the piston ends 45 and 55 of the two projectiles 20 and 24. Inside the container 59 there is disposed a preselected quantity of liquid or gel-like material containing the propping agent 60. As hereinbefore stated, the propping agent 60 is particulate in form, and therefore the particles are preferably disposed in colloidal suspension in the liquid or gel-like medium in the container 59. Furthermore, the container 59 should preferably be substantially filled in order that it may be enabled to resist being crushed by the weight of the fluid in the casing 4.

As may be seen in FIGURE 2, there is provided both an upper and a lower gun 20 and 24 mounted in opposing relationship to each other. Although two such pressure-producing devices are preferable to only one, it should be understood that if the lower propelling charge 26 were omitted, and if the weight of the lower gun 24 and projectile 50 were made sufficiently great relative to the upper gun 20 and projectile 40 so that recoil would not be significant, then only one such pressure-producing device need be provided.

It is preferable that the upper and lower piston ends 45 and 55 be spaced apart, prior to firing, at least a dis-

tance greater than the thickness of the formation 8. Further, it is preferable that the container 59 be at least substantially filled with liquid and propping agent 60, and that the volume or quantity selected to be such as to occupy substantially all of the section of the borehole which is adjacent the selected formation 8. As hereinbefore stated, it is also preferable that the upper and lower propelling charges 22 and 26 be equal in magnitude and be fired simultaneously to avoid ineffectively driving the apparatus up and down the casing 4 or borehole. Furthermore, it is necessary that the two propelling charges 22 and 26 be large enough to produce, in combination, a pressure large enough to overcome the formation pressure in the region more or less immediately surrounding the perforations 10.

Although the forms of the present invention which are described hereinbefore are primarily intended for use in a cased borehole, it should be apparent that the present invention is also useful to improve, or even to initiate, fluid flow from formations tapped by uncased boreholes. In such a case, the piston ends 45 and 55 of the projectiles 20 and 24, and the gaskets 46 and 56, must be large enough to provide a reasonably effective gas-tight seal against the borehole wall 2 even if the surface of the borehole wall 2 is relatively irregular. Moreover, the upper and lower propelling charges 22 and 26 must be large enough to produce a force sufficient to produce new cracks 12 in the formation 8 materials.

Numerous other variations and modifications may obviously be made in the structures and techniques described herein without departing from the basic concept or principle of the present invention. Accordingly, it should be clearly understood that the forms of the invention described herein are depicted in the accompanying drawing are illustrative only, and are not intended to limit the scope of the invention.

What is claimed is:

1. Apparatus for stimulating fluid flow from a sub-surface earth formation traversed by a borehole containing a casing having at least one perforation, said apparatus comprising:

- an elongated strength member disposed longitudinally in said casing adjacent said earth formation,
- a collapsible container means disposed generally about said strength member,
- a quantity of liquid disposed in said collapsible container means,
- a quantity of particles of a propping agent suspended in said liquid,
- first gun means connected to the upper end of said strength member and having its muzzle end directed downward in said casing toward said container means,
- second gun means connected to the lower end of said strength member and having its muzzle end directed upward in said casing toward said container means,
- first projectile means slidably disposed about said strength member and slidably disposed in said first gun means,
- a first propelling charge disposed in said first gun means for discharging said first projectile means from said first gun means,
- first compressing means for outwardly expanding in a substantially fluid-tight manner against the inside of said casing in response to downward urging by said first projectile means,
- second projectile means slidably disposed about said strength member and slidably disposed in said second gun means,
- a second propelling charge substantially equal to said first charge and disposed in said second gun means for discharging said second projectile means from said second gun means,
- second compressing means for outwardly expanding in a substantially fluid-tight manner against the inside

of said casing in response to upward urging by said second projectile means, and
actuating means for simultaneously energizing said first and second propelling charges.

2. Apparatus for stimulating fluid flow from a sub-surface earth formation traversed by a borehole containing a casing having at least one perforation, said apparatus comprising:

- a collapsible container means,
- a quantity of liquid and particles of propping agent disposed in said collapsible container means,
- first gun means having its muzzle end directed downward in said casing toward said container means,
- second gun means having its muzzle end directed upward in said casing toward said container means,
- first projectile means slidably disposed in said first gun means,
- a first propelling charge disposed in said first gun means for discharging said first projectile means from said first gun means,
- first compressing means for outwardly expanding in a substantially fluid-tight manner against the inside of said casing in response to downward urging by said first projectile means,
- second projectile means slidably disposed in said second gun means,
- a second propelling charge substantially equal to said first charge and disposed in said second gun means for discharging said second projectile means from said second gun means,
- second compressing means for outwardly expanding in a substantially fluid-tight manner against the inside of said casing in response to upward urging by said second projectile means, and
- actuating means for simultaneously energizing said first and second propelling charges.

3. Apparatus for stimulating fluid flow from a sub-surface earth formation traversed by a borehole, said apparatus comprising:

- a collapsible container means,
- a quantity of liquid and particles of propping agent disposed in said collapsible container means,
- first gun means having its muzzle end directed downward in said casing toward said container means,
- second gun means having its muzzle end directed upward in said casing toward said container means,
- first projectile means slidably disposed in said first gun means,
- a first propelling charge disposed in said first gun means for discharging said first projectile means from said first gun means,
- second projectile means slidably disposed in said second gun means,
- a second propelling charge substantially equal to said first charge and disposed in said second gun means for discharging said second projectile means from said second gun means, and
- actuating means for simultaneously energizing said first and second propelling charges.

4. Apparatus for stimulating fluid flow from a sub-surface earth formation traversed by a borehole, said apparatus comprising:

- a collapsible container means,
- a quantity of liquid and particles of propping agent disposed in said collapsible container means,
- first compressing means mounted above said container means for compressing said container means and urging said liquid and propping agent downwardly and outwardly in said borehole,
- second compressing means mounted below said container means for compressing said container means and urging said liquid and propping agent upwardly and outwardly in said borehole, and
- actuating means for simultaneously energizing said first and second compressing means.

5. A method of increasing the rate of fluid flow from a fluid-containing earth formation penetrated by a borehole, the method comprising the steps of:

positioning an elongated, liquid-filled, collapsible member in the borehole adjacent said formation, and simultaneously exerting oppositely directed forces on each end of said collapsible member, collapsing said member lengthwise to urge said liquid against the formation with a force at least sufficient to open fissures in the formation.

6. The method of claim 5 wherein said last-mentioned step includes simultaneously detonating an explosive charge located externally of and adjacent each end of said collapsible member to create said oppositely directed forces.

7. The method of claim 5 and including the step of mixing a particulate propping agent into said liquid whereby said propping agent will be carried into said open fissures upon the collapse of said member.

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