ABSTRACT: This specification discloses a method of forming two vertically disposed fractures communicating with a well equipped with a casing penetrating a subterranean earth formation having a known preferred fracture orientation. Openings are formed through the well on opposite sides of the casing located such that they lie in a vertical plane which extends transversely of the fracture orientation. Hydraulic pressure is then applied through the openings to form a fracture at the openings on one side of the well. These openings are then temporarily sealed by ball sealers and hydraulic pressure applied to form a fracture at the openings on the other side of the well. The fractures may be acidized.
METHOD OF FORMING TWO VERTICALLY DISPOSED FRACTURES FROM A WELL PENETRATING A SUBTERRANEAN EARTH FORMATION

BACKGROUND OF THE INVENTION

This invention is directed to a method of fracturing a subterranean earth formation from a well penetrating the formation. More specifically, this invention is directed to a method of forming two vertically disposed fractures which communicate with the well and extend in the direction of a known preferred fracture orientation.

It is known in the prior art to fracture subterranean earth formations both horizontally and vertically by applying sufficiently high hydraulic pressure to the formation. Generally it is considered that the applied must be greater than the overburden pressure if horizontal fractures are to be created. This pressure normally is on the order of 1 p.s.i. per foot of overburden. However, it has been found that in relatively deep formations, fracturing takes place at a lesser pressure than would be expected for horizontal fractures. It is generally accepted that this is because vertical rather than horizontal fractures are formed in these formations. Though no definite depth can be given below which vertical rather than horizontal fractures are formed, vertical fractures normally are preferentially formed at depths greater than about 2000 to 3000 feet.

As explained in U.S. Pat. No. 2,932,319, Popham, vertical fractures can be formed from a cased well by forming a vertical slot through the casing and forcing a low fluid loss fracturing fluid outward through the slot under sufficient pressure to fracture the adjacent formation. Also taught in U.S. Pat. No. 3,270,816, Staatd, is a method of orienting vertical fractures in a formation from two-cased wells penetrating the formation such that the fractures intersect and form fluid communica
tion between the wells. U.S. Pat. No. 3,028,914, Flickinger, teaches temporarily plugging existing fractures, e.g. with ball sealers, and then making a number of perforations through the casing and injecting a quantity of fracturing liquid into the well to create fractures at the elevation of these perforations. U.S. Pat. No. 3,431,977, East al., recognizes that there exists in some formations a natural plane of weakness which under some conditions causes vertical fractures to form in this plane.

SUMMARY OF THE INVENTION

This invention is related to a method of forming two vertically disposed fractures which communicate with a cased well penetrating a subterranean earth formation having a preferred fracture orientation. The casing is selectively opened to the formation through first and second openings located on opposite sides of the casing and lying in a vertical plane which extends transversely of the fracture orientation. Hydraulic pressure is applied through these openings to form a first vertically disposed fracture communicating with the well and extending into the formation along the direction of the preferred fracture orientation. The opening in the casing which communicates with the first fracture is then temporarily sealed and hydraulic pressure is applied to the formation through the second opening to form a second vertically disposed fracture communicating with the well and extending into the formation along the direction of the preferred fracture orientation.

In another embodiment of this invention the second opening in the casing is formed after the first fracture is formed. Thereafter, hydraulic pressure is applied to the formation through the second opening to form a second fracture, the first opening being sealed during this step. In a further aspect of the invention, acid is applied through the fractures to further improve the permeability of the fractures and surrounding formation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of an earth formation having a preferred fracture orientation; and FIG. 2 is a cross-sectional view of a well penetrating an earth formation; and FIG. 3 is a sectional view taken along the line 3-3 of FIG. 2 showing two vertical fractures communicating with the well.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1 there is shown a plan view of an earth formation 13 having a preferred fracture orientation indicated by a plurality of fractures 3 oriented in the same general direction. By way of illustration, the preferred fracture orientation is shown as extending in a north-south direction. This orientation exists because of naturally occurring planes of weakness existing in the earth formation. It is known that subterranean earth formations are joined in a manner similar to surface rock. Therefore, surface measurements may be employed reasonably close indication of the preferred fracture orientation.

The preferred fracture orientation may also be determined from measurements taken in wells penetrating the subterranean earth formations of interest. For example, impression packer surveys may be run throughout the area to determine the fracture orientation. Borehole television shots through fractures, particularly good method of determining the preferred fracture trends. Borehole television surveys are discussed in an article by J. Zemanek, et al., entitled "The Borehole Televiewer - A New Logging Concept for Fracture Location and Other Types of Borehole Inspection,", JOURNAL OF PETROLEUM TECHNOLOGY, Vol. XXI (June 1969), pp. 762-774.

Referring to FIG. 2 there is shown a well 9 extending from the earth's surface 11 and penetrating a subterranean earth formation 13 such as an oil or gas reservoir. Well 9 is equipped with a casing 15 cemented by a cement sheath 17 and having a casinghead 19. A flowline 25 extends from the casing at the surface for the introduction and withdrawal of fluids.

In carrying out the invention, the well 9 is selectively opened to the formation through openings 21 and 23 which are located at opposite sides of casing 15 and which lie in a vertical plane extending transversely of the preferred fracture orientation. Thus, where the preferred fracture orientation is north-south as shown in FIG. 1, the openings 21 and 23 will lie in a plane extending generally in an east-west direction. The openings 21 and 23 may be formed in the casing by any suitable technique. For example, each of these openings may comprise one or more perforations or one or more slots. However, it is desirable that the casing be opened to the formation throughout a substantial vertical distance. Thus, it is preferred in carrying out the invention to form each of openings 21 and 23 of a plurality of vertically aligned perforations as indicated by reference numerals 21a and 23a, respectively, or of elongated vertical slots such as shown in the aforementioned patent to Popham.

After openings the well to the formation, fracturing fluid is pumped through conduit 25 and into casing 15 and applied to formation 13 through openings 21 and 23. The pressure is increased until a first fracture forms and is propagated through the formation. The formation will form in formation 13 adjacent one of openings 21 and 23 and will be propagated through formation 13 along the direction of the preferred fracture orientation, north-south in this example. Thus, for explanation purposes, it will be assumed that a first vertically disposed fracture 29 (shown in FIG. 3) is formed adjacent opening 21 and is propagated through formation 13 and communicates with the outside east extremity of well 9.

After propagation of fracture 29 into formation 13, opening 21 is temporarily sealed. This may be accomplished by any suitable technique. For example, ball sealers of the type disclosed in the aforementioned patent to Flickinger may be circulated with the fracturing fluid through conduit 25 into the well. These ball sealers will temporarily seal opening 21 through which fluid is flowing into fracture 29 while leaving unobstructed opening 23. With opening 21 sealed, the hydra-
lic pressure is again increased until a second vertically disposed fracture 31 (shown in FIG. 3) forms adjacent second opening 23 and is propagated through formation 13. This fracture communicates with the outside west extremity of well 9. Thus, two vertical fractures are formed and propagated in formation 13 in a north-south direction and are approximately parallel one to the other. These two fractures effect substantial improvement in the communication between well 9 and formation 13 over that normally afforded by a single vertical fracture.

The fractures formed will tend to follow the preferred fracture orientation regardless of the location of the opening in casing 15. Thus from an examination of FIG. 3 it will be recognized that the vertical plane along which openings 21 and 23 lie should be as close to normal with respect to the preferred fracture orientation as possible in order that the fractures 29 and 31 intersect the well 9 at opposite sides thereof. The fractures thus are spaced a maximum distance apart. This lessens the chance that they will merge and form a single fracture in the formation; or, should they merge, they will do so at an extended distance from well 9.

In the above description it was assumed that both of openings 21 and 23 were formed prior to fracturing of the formation. This usually will be desirable from the standpoint of economy since both openings can be formed in a single operation with a perforator having diametrically opposed guns or jets. In addition, the openings can be accurately oriented 180° apart. However, first openings opening 21 and second opening 23 in well 9 may be sequentially formed. For example, first opening 21 may be formed and fracturing fluid applied through this opening to form fracture 29. Thereafter, second opening 23 may be formed and first opening 21 temporarily sealed and fracturing fluid applied through opening 23 to form fracture 31. In some cases this is desirable because it ensures that a first vertical fracture intersects the wellbore in communication with the first opening and it can be easily determined that this first opening is temporarily sealed prior to forming a second vertical fracture on the opposite side of the wellbore.

Thus, the formation of two vertical fractures in the formation and communication of each fracture with the well are more positively known. These vertical fractures intersect the outside extremities of well 9 and provide good communication between the well 9 and formation 13. In accordance with a further aspect of the invention, even greater communication is provided by acidizing well 9 after at least one but preferably after both vertical fractures are formed in formation 13. Acid, as is used in conventional acidizing techniques, e.g. 15-28 percent hydrochloric acid in carbonate formations or hydrochloric acid containing 3-6 percent hydrofluoric acid in sandstone formations, is injected into well 9 and thence into the vertical fractures 29 and 31 in formation 13 (FIG. 3). This results in acid penetrating deep into formation 13 and attacking the matrix surrounding the fractures thereby improving the conductivity of formation 13 surrounding fractures 29 and 31 as indicated by zones 33 and 35.

1 claim:

A method of forming two vertically disposed fractures communicating with a well equipped with a casing penetrating a subterranean earth formation having a preferred fracture orientation, comprising:

a. selectively opening said well to said formation by forming a first opening and a second opening in said casing, said openings being located on opposite sides of said casing and lying in a vertical plane which extends transversely of said fracture orientation;
b. applying hydraulic pressure through said first opening and said second opening to form a first vertically disposed fracture communicating with said well and extending into said formation along the direction of said preferred fracture orientation;
c. sealing temporarily the opening in said casing which communicates with said first vertically disposed fracture; and

d. applying hydraulic pressure to said formation through the other opening in said casing to form a second vertically disposed fracture communicating with said well and extending into said formation along the direction of said preferred fracture orientation.

2. The method of claim 1 wherein each of said first and said second openings comprises a plurality of vertically aligned perforations in said casing.

3. The method of claim 1 wherein each of said first and said second openings comprises an elongated vertical slot.

4. The method of claim 1 wherein ball sealers are used to seal temporarily said first opening in said casing.

5. The method of claim 1 further comprising injecting acid into said first and said second vertically disposed fractures to improve the conductivity of the fractures and of the formation surrounding them.

6. A method of forming two vertically disposed fractures communicating with a well equipped with a casing penetrating a subterranean earth formation having a preferred fracture orientation, comprising:

a. selectively opening said well to said formation by forming a first opening in said casing at a first location in a vertical plane which extends transversely of said fracture orientation;
b. applying hydraulic pressure through said first opening to form a first vertically disposed fracture communicating with said well and extending into said formation along the direction of said preferred fracture orientation;
c. selectively opening said well to said formation by forming a second opening in said casing at a second location on the opposite side of said casing from said first opening and lying in said vertical plane which extends transversely of said fracture orientation;
d. sealing temporarily said first opening; and

e. applying hydraulic pressure through said second opening to form a second vertically disposed fracture communicating with said well and extending into said formation along the direction of said preferred fracture orientation.

7. The method of claim 6 wherein each of said first and said second openings comprises a plurality of vertically aligned perforations in said casing.

8. The method of claim 6 wherein each of said first and said second openings comprises an elongated vertical slot.

9. The method of claim 6 wherein ball sealers are used to seal temporarily said first opening in said casing.

10. The method of claim 6 further comprising injecting acid into said first and said second vertically disposed fractures to improve the conductivity of the fractures and of the formation surrounding them.