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FRACTURE PLACING METHOD

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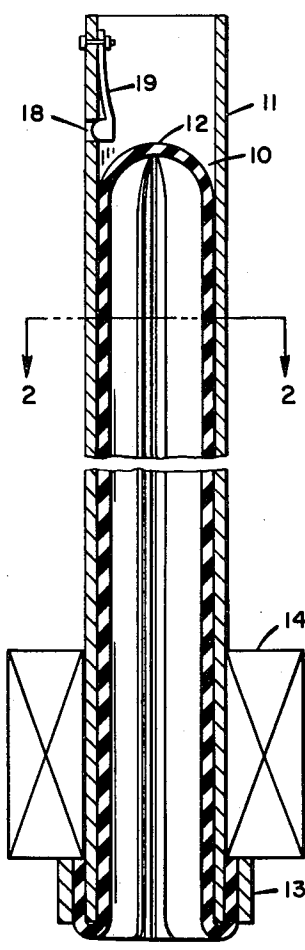


FIG. 1

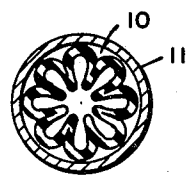


FIG. 2

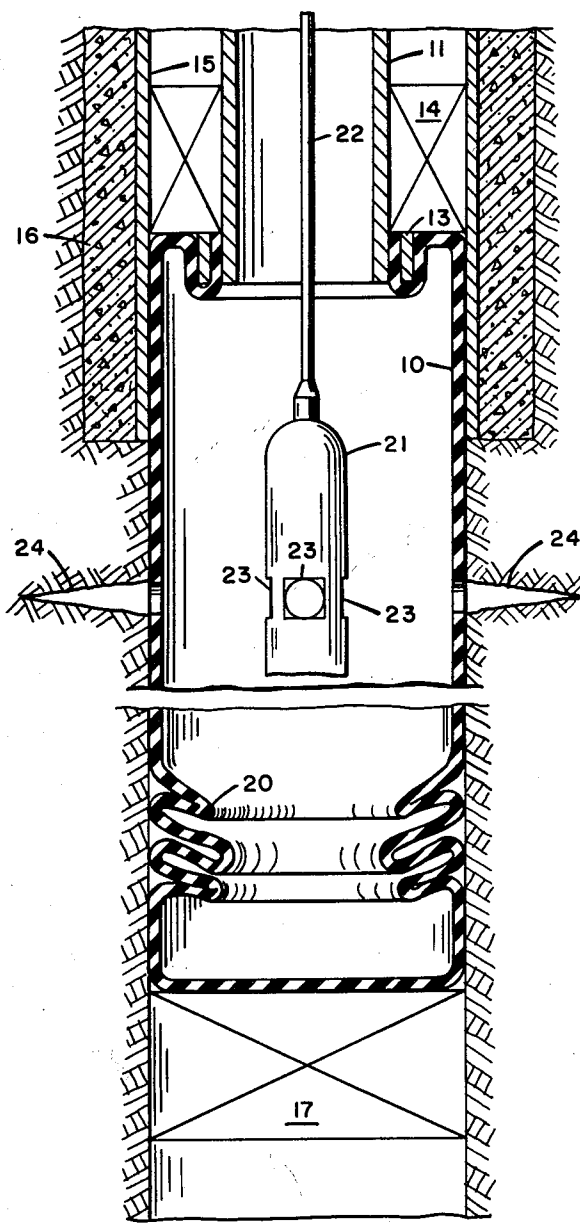


FIG. 3

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1

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FRACTURE PLACING METHOD

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1 Claim. (Cl. 166—35)

This invention relates to a method and apparatus for fracturing earth formations penetrated by wells. The principal object of the invention is to form substantially horizontal fractures in the formations only at the desired level in the well.

In general, I accomplish the objects of my invention by expanding a substantially impermeable bag in the well at the level where a fracture is desired, forming at least one hole through the bag and into the formation at the level in the well where the fracture is desired, and pumping liquid through the hole to form a horizontal fracture.

In the drawing,

FIGURE 1 is a longitudinal section through one embodiment of apparatus suitable for my purposes.

FIGURE 2 is a transverse section through 2—2 of FIGURE 1.

FIGURE 3 is a view partly in section of the apparatus shown in FIGURE 1 after the bag has been expanded at the desired level in the well and passages have been formed through the bag and into the formation.

The bag is at least substantially as large in circumference as the well in which it is to be set. Thus, it need not be greatly stretched to fit against the well wall and form a substantially impermeable barrier to the flow of fracturing fluid into the formation at points other than the hole or holes which penetrate the bag and extend into the formation. Since flow of fracturing fluid is confined to a definite level in the formation, the horizontal fracture must, of course, form only at that level.

If a bag is used which is not substantially as large as the well, it tends to collapse when the hole is formed through it. This exposes the entire formation to fracturing pressure. The necessity of using a bag "having a circumference at least as great as the circumference of the well" will be apparent from this explanation. That is, the circumference of the bag should be no more than two or three percent less than the circumference of the well.

There is no particular upper limit on the circumference of the bag. When fracturing in a portion of the well having enlarged sections, it is advisable to use a bag having a circumference two or three times as great as that of the bit used to drill the well. Such a bag will, of course, have a circumference several times as great as portions of the well which are not enlarged. The important point is to use a bag which has a circumference at least substantially as large as the greatest circumference of the portion of the well in which the bag is to be expanded. Use of a bag considerably larger than this minimum size is generally advisable, of course, and is preferred.

Use of impermeable bags for lining wells in fracturing operations has been previously proposed in references such as U.S. Patent 2,798,557 Sewell and U.S. Patent 2,848,052 Stinson. The processes of these references, however, formed vertical fractures. Pressure was applied within the bag until the tensile strength of the surrounding formations was exceeded. Thereupon, the formation fractured along the axis of the well; that is, vertically.

It is my purpose to form a substantially horizontal fracture. I have found that if a hole is formed in the bag and extending into the formation, sufficient fracturing fluid can enter the formation through this path to apply

2

a lifting action and form a substantially horizontal fracture. Preferably, more than one passage should be formed through the bag and into the formation. All holes or passages should be near the plane of the desired fracture. The greater the number of holes, the greater is the assurance that the fracture will be in the desired plane. In addition, the greater the penetration of the holes or passages into the formation, the greater is the flow of fluids into the formation at the desired level and the better is the assurance of obtaining the desired fracture. If the holes do not penetrate the formation, only very small areas of the formation are exposed to the fracturing fluid and little flow into the formation occurs. The danger of vertical fracturing then becomes great. For this reason, the holes through the bag should also penetrate the formation to a depth of at least an inch or two and preferably much more.

While reference has been made to forming the perforations in a horizontal plane to form a horizontal fracture, it will be understood that it will sometimes be desirable to form a fracture tilted slightly to the horizontal. This may be desirable, for example, to make the plane of the fracture coincide with the bedding planes in tilted formations. The term "substantially horizontal," as used herein, should be interpreted to include such small variations from horizontal.

On the other hand, when reference is made to forming a hole in the bag and formation "in the plane" in which a fracture is desired, it will be understood that this is not an absolute requirement. Again, substantial compliance with the requirement is adequate. For example, it may be desired to form a fracture along the bedding planes of slightly tilted formations. In such cases, firing the holes through the bag in a horizontal plane should be considered to be "in the plane" in which a fracture is desired.

Considering the drawing in more detail, FIGURE 1 shows a bag 10 folded to fit up inside the bottom of a tubing string 11. The folding of the bag is shown more clearly in cross-sectional view in FIGURE 2. One end of the bag is closed as shown at 12 in FIGURE 1. The other end is open. The open end is attached to the bottom of tubing 11 by clamp 13. Above the clamp is a packer 14 shown diagrammatically in FIGURE 1. Just above the bag, a port 18 is provided through the wall of the tubing. This port is normally closed by spring check valve 19.

In FIGURE 3, packer 14 is shown set inside casing 15 which has been cemented in the well by cement 16. The bag 10 is shown expanded against the uncased wall of the well below the casing. The top of the bag is provided with mechanical support by packer 14. Bridging plug 17 provides support for the bottom of the bag. The bag should be longer than the distance between packers 14 and 17 so it will not have to stretch to reach the supporting packers. Therefore, the bag will be somewhat folded in some areas as at 20. A perforator assembly 21 is suspended in the well by cable 22. The assembly carries four jet or bullet perforator units 23 which have been used to form passages 24 extending through the bag wall and into the formation in a substantially horizontal plane.

In operation, bridging plug 17 is first set in the well slightly below the level at which a fracture is desired. Then the bag is lowered into the well in the form shown in FIGURE 1. The tubing is initially empty. As the assembly enters liquid in the well, the pressure increases inside the bag. Before this pressure can become great enough to damage the bag, however, spring check valve 19 allows liquid to enter the tubing through port 18 and limits the pressure differential across the bag. When the bag assembly reaches a point slightly above the level

3

at which the fracture is desired, packer 14 is set. While FIGURE 3 shows the packer as being set in the casing, it will be apparent that an open hole packer may be set in the uncased portion of the well if desired. Pressure is then applied to the inside of the tubing to force the bag out of the tubing. Further application of pressure unfolds the bag and expands it out against the wall of the well, upward against packer 14 and downward against bridging plug 17.

Perforating tool assembly 21 is then lowered into the well to a position in which perforator units 23 are at the level where the fracture is desired. Fracturing liquid is then pumped into the tubing. Before the pressure reaches a value at which there is danger of vertical fracturing, perforator units 23 are fired. Further pumping of fracturing liquid then forces this fluid out through passages 24 into the formation. A lifting action is thus developed to form a horizontal fracture approximately in the plane of the perforations. The pressure should, of course, be limited to a value insufficient to form a vertical fracture.

The fracturing fluid may be any of the water, oil, or emulsion-base fluids commonly used for this purpose. Preferably a low penetrating fluid, as described in more detail in U.S. Reissue Patent 23,733 Farris, should be used. A fracture propping agent such as sand, metal particles or the like, should be included in at least a portion of the fracturing fluid. Fracturing pressure may be applied by any convenient means such as pumps, gas pressure, slow burning explosives, or the like.

After fracturing operation, perforating tool 21 is removed from the well. Packer 14 is then unseated. The tubing should be swabbed and pressure should be applied to the annular space between the tubing and casing to collapse the bag. The tubing and bag can then be pulled from the well. Occasionally, fracture propping agent in the bag below the level of the fracture will hold the bottom portion of the bag in the well so that only the top portion is removed. If no producing zones are present below the fracture, the presence of the bridging plug, propping agent, and the bottom part of the bag are not objectionable. It is a simple matter, however, to wash the propping agent out of the bag and fish out the bag and bridging plug if desired.

In the drawing, the bag is shown as being made of rubber. Soft synthetic rubber is a preferred material since it is very flexible, is substantially impervious, and is sufficiently elastic to stretch slightly without bursting if necessary to conform to rough portions of the well wall. Other materials, such as flexible plastics like polyethylene and vinyl polymers, or fabrics such as heavy canvas, may also be used if desired. The bag may be reinforced with threads or fibers of metal, cotton, glass, nylon or the like. No great amount of reinforcing is ordinarily required or desirable, however. A wall thickness of between about $\frac{1}{16}$ inch and about $\frac{1}{4}$ inch is preferred although other thicknesses will be advisable in some cases.

The material of which the bag is made should preferably be inert to well fluids. For example, synthetic rubber such as neoprene is preferred to natural rubber since the latter softens in the presence of oil. It should be noted, however, that natural rubber is quite satisfactory in most cases since many hours are required for serious softening to occur. When the term "at least temporarily inert" is used herein, it should be interpreted to mean that the material retains its strength sufficiently to perform the desired sealing action over the period of time required for completing the fracturing operation.

Many variations of apparatus for accomplishing my purposes will be apparent to those skilled in the art. For example, instead of setting bridging plug 17 in the well, the well may be filled with sand, cement or the like, to support the bottom of the bag. If the bag is set near the bottom of a well, the bottom of the well itself will provide the necessary support.

4

Other supporting means, such as petal baskets, may be used to provide mechanical support for the upper end of the bag in some cases. The bag, instead of being inserted inside the tubing, may be folded around the outside of a perforated mandrel on which packer 14 is mounted at the top and packer 17 is carried at the bottom. Again, petal baskets or other supports may be substituted for the top and bottom packers in some cases. The perforator, instead of being withdrawn after the fracturing operation, may be withdrawn before this step is performed. Many other variations can be made within the scope of my invention which should, therefore, be limited only by the terms of my claim.

The bag should be lowered into the well in a collapsed form; that is, in a form having a diameter less than the smallest diameter of the well through which the bag must be lowered. The purpose is to prevent excessive contact between the bag and the well wall, since such contact might result in wearing a hole in the bag. The collapsed form shown in FIGURE 1 is preferred since in this form the bag is best protected from wear.

It may be advisable in some cases to decrease the pressure differential across the bag and its mechanical support. This is particularly desirable when a support of rather limited strength such as a petal basket is used. In such cases, at least a small amount of pressure may be applied to the well above, below, or both above and below the bag. Care should be taken in such cases to avoid applying a pressure sufficient to fracture any formations which may be exposed to such pressure. In an arrangement such as that shown in FIGURE 3, however, it will be apparent that a high pressure can be applied to the annular space between the casing and tubing. This pressure may be almost as great as that applied within the bag. In such a case, little, if any, mechanical support for the end of the bag will be required. In any case, application of some pressure outside the ends of the bag is generally desirable, wherever possible, to decrease the load which must be carried by the mechanical supports for the ends.

My invention will be better understood by consideration of the following example. A shallow well was drilled into a limestone formation to a depth of 19 feet and casing was set in the well. The well was then deepened to 32 feet using a $4\frac{1}{8}$ inch bit. A neoprene bag, $4\frac{3}{4}$ inch in diameter and 10 feet long with a wall thickness of $\frac{3}{32}$ inch, was next placed in the well. The bag was tied at its ends to a mandrel about $2\frac{1}{2}$ inch in diameter and the assembly was lowered to the bottom of the well by use of a section of 2-inch tubing. Mounted in the mandrel inside the bag was a jet perforator unit with electrical leads running up inside the mandrel and tubing to the surface. At the top of the bag a downwardly facing cup-type packer was mounted on the mandrel to provide mechanical support for the top of the bag. The bottom of the bag was supported by the bottom of the well. An upwardly facing cup-type packer was provided just above the downwardly facing one to prevent any tendency of the assembly to be blown out of the well when the shaped explosive charge was fired.

After the bag was placed in the bottom of the well, fracturing fluid was pumped into the tubing to develop a pressure of 500 p.s.i.g. The perforator was then fired. Pumping of fracturing fluid was continued to fracture the formation. The tubing, mandrel, and bag were then removed from the well.

Before the fracturing operation, a permeability survey of the well had been made by pumping liquid into the formation between opposed cup packers set 6 inches apart. Natural fractures were located at depths of 21 and 28 feet. The perforator was set at a depth of 25 feet. After the fracturing operation, a second survey confirmed the presence of the old fractures and located a new fracture only at a depth of 25.5 feet. Since no fracture could be found slightly above or below this level, it is apparent that the fracture was substantially horizontal.

5

I claim:

A process for forming only at the desired level in the uncased portion of a well a substantially horizontal fracture in a formation penetrated by the well comprising lowering into said well, to the level at which said fracture is desired, a flexible, substantially impermeable bag, at least temporarily inert to well fluids, said bag having a circumference at least as great as the largest circumference of the portion of the well into which the bag is to be expanded, and said bag being lowered in a collapsed form having a diameter less than that of any portion of the well through which the bag must pass, forcing fluid into said bag after it reaches said level to expand said bag against the formation, detonating at least one jet perforator to form at least one hole extending through said bag and into said formation only in the hori-

6

zontal plane in which said fracture is desired, and forcing liquid through said at least one hole in said bag and into said formation at a rate sufficient to form said substantially horizontal fracture at said desired level.

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