

Oct. 25, 1966

F. A. SMITH

3,280,913

VERTICAL FRACTURING PROCESS AND APPARATUS FOR WELLS

Filed April 6, 1964

2 Sheets-Sheet 1

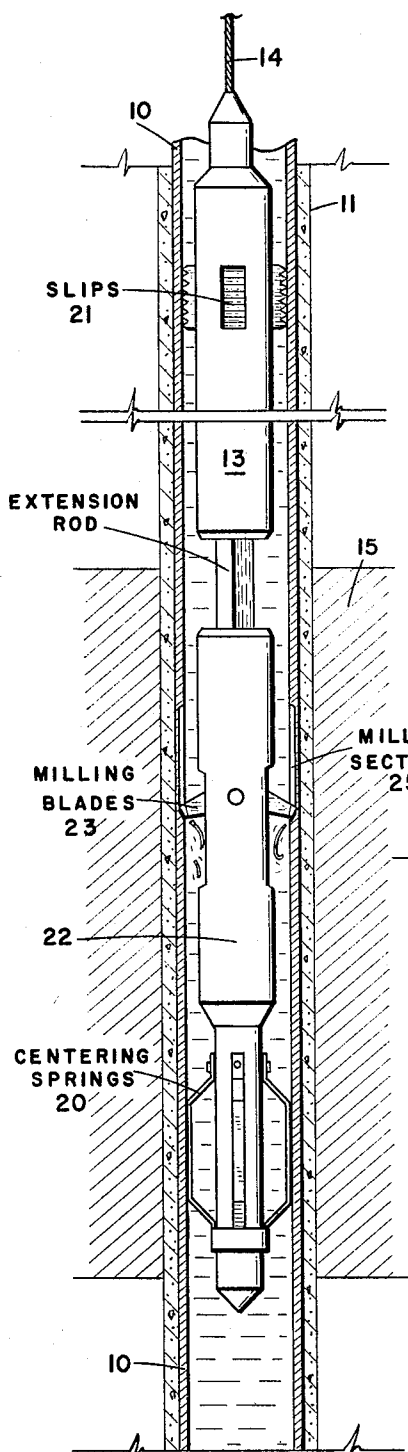


FIG. 1.

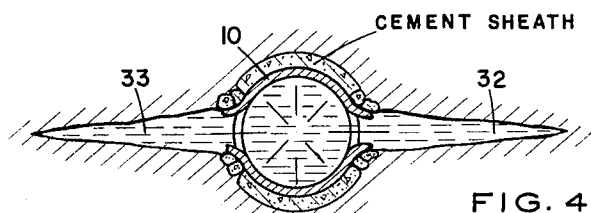


FIG. 4.

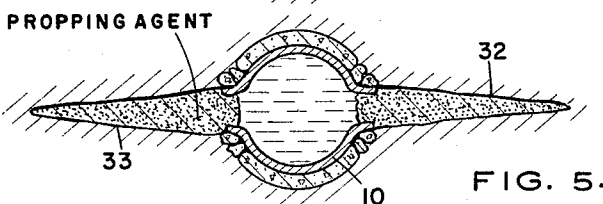


FIG. 5.

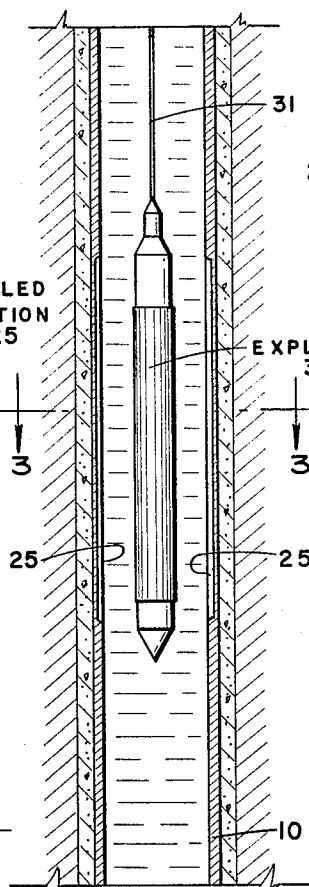


FIG. 2.

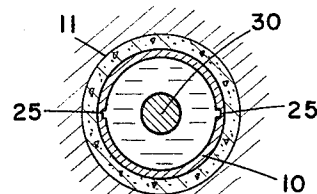


FIG. 3.

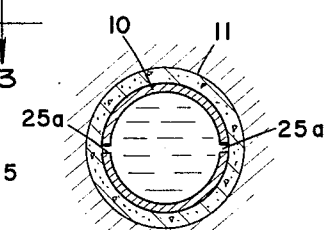


FIG. 3A.

INVENTOR.
FLOYD A. SMITH,
BY *John D. Schneider*
ATTORNEY.

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F. A. SMITH

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2 Sheets-Sheet 2

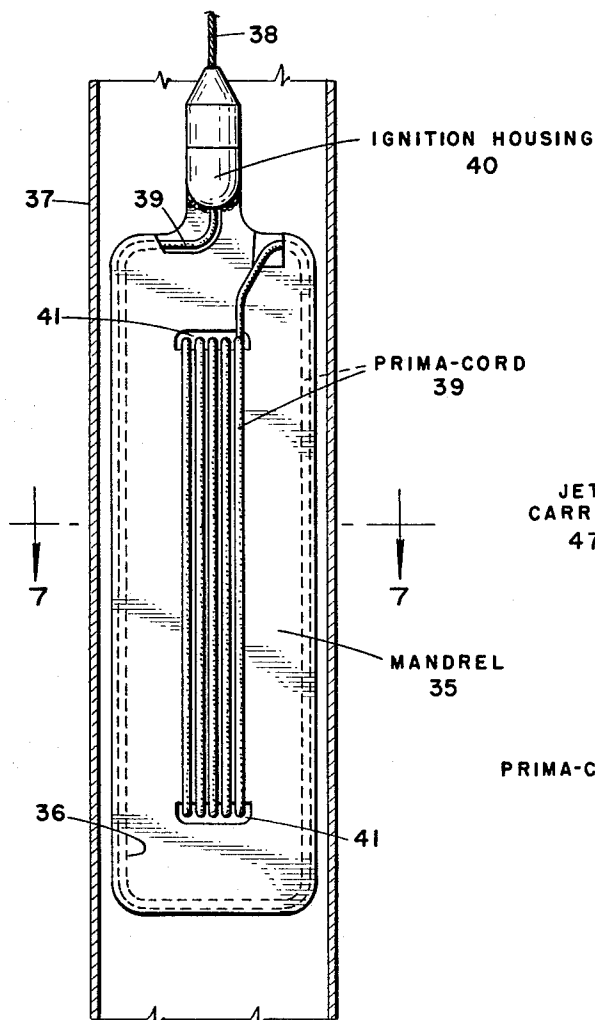


FIG. 6.

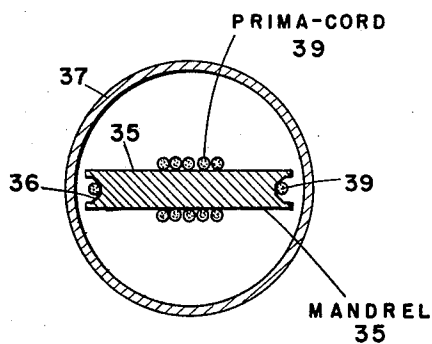


FIG. 7.

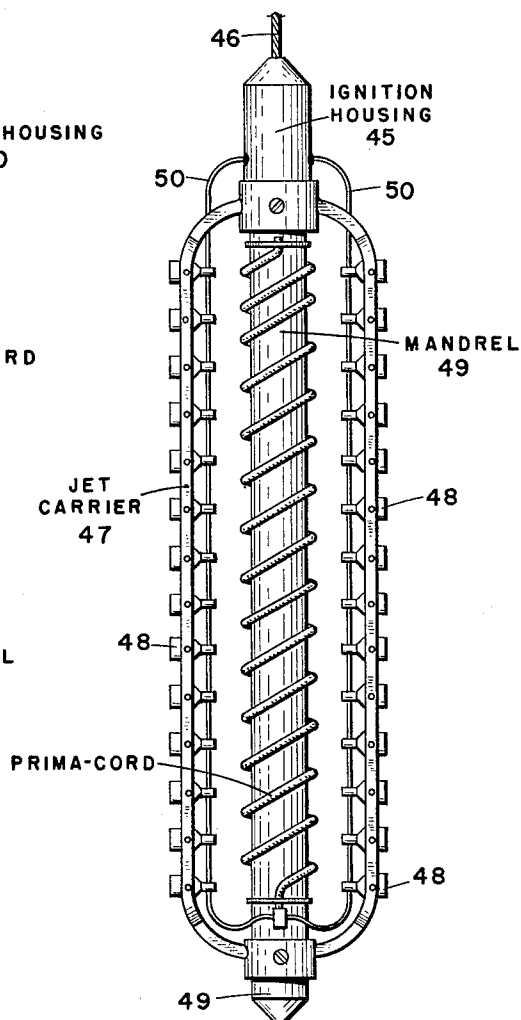


FIG. 8.

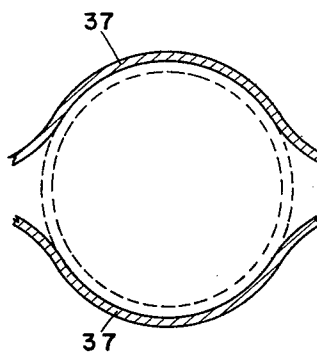


FIG. 9.

INVENTOR
FLOYD A. SMITH,
BY *John S. Schneider*
ATTORNEY.

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VERTICAL FRACTURING PROCESS AND APPARATUS FOR WELLS

Floyd A. Smith, Tulsa, Okla., assignor, by mesne assignments, to Esso Production Research Company, Houston, Tex., a corporation of Delaware

Filed Apr. 6, 1964, Ser. No. 357,604

9 Claims. (Cl. 166—35)

The present invention relates to stimulating formations and, more particularly, to permanently propping the mouth of a vertical formation fracture.

Hydraulic fracturing processes, in which a fracturing fluid is forced into a producing well in sufficient volume and under sufficient pressure to rupture a subsurface formation, have found only limited use in the stimulation of damaged formations, particularly those which are relatively soft, because it has been difficult to permanently prop the portion of the fracture nearest the well bore (fracture mouth) penetrating the damaged formation.

The instant invention overcomes disadvantages in each hydraulic fracturing processes by causing the wall of the well casing pipe string, which is arranged in the well bore penetrating the formation to be stimulated, to rupture, expand, and permanently prop the mouth of a vertical fracture formed in said formation. The technique is useful in any type of formation.

Briefly, the invention resides in weakening the well pipe axially along two lines spaced approximately 180° from each other through the interval or formation to be stimulated mechanically, by milling or cutting, or explosively by use of directionally oriented explosive charges or radially directed jet charges or guns after which a well pipe or casing forming charge is detonated to force the well pipe halves defined by said spaced lines apart past their yield points, thereby creating and permanently propping with the expanded casing a fracture in the formation. Long intervals may be successfully fractured in this manner by leaving occasional spaces or blanks so that the expanded casing walls are provided with necessary support.

Thus, a primary object of this invention is to provide an improved well formation stimulation or fracturing technique.

This and other objects as well as advantages of the invention will be more apparent from a more detailed description thereof when taken with the drawings wherein:

FIG. 1 is a vertical, partly sectional view showing representative apparatus that may be used to weaken sections of the well pipe it is desired to rupture and expand;

FIG. 2 is a vertical, partly sectional view illustrating a further step; viz., the positioning of an explosive charge when the milling apparatus of FIG. 1 is used to weaken the well pipe;

FIG. 3 is a view taken along lines 3—3 of FIG. 2;

FIG. 3A is a plan view of the well pipe similar to that shown in FIG. 3 except the well pipe has been cut completely through on each opposing side;

FIG. 4 is a plan view illustrating the appearance of the well pipe and formation fracture following detonation of the explosive charge of FIG. 2;

FIG. 5 is a plan view similar to that of FIG. 4 illustrating a further step permitted by this technique, that of moving fracture fluid containing propping agents into the fracture that has been formed;

FIG. 6 is a vertical, partly sectional view of one type of combination tool which may be used for explosively weakening and expanding the well pipe;

FIG. 7 is a view taken along lines 7—7 of FIG. 6;

FIG. 8 is a vertical view of another type of combination tool for explosively weakening and expanding the well pipe; and

FIG. 9 is a plan view of the well pipe after expansion by the explosive elements of the tools of FIGS. 6 and 8.

A milling tool 13 is seen in FIG. 1 suspended in a well pipe 10 from a cable 14. It is positioned adjacent a formation or interval 15 which it is desired to fracture and which is penetrated by a well bore 11 in which is arranged well pipe 10. Tool 13 mills and weakens casing pipe 10 along two lines spaced approximately 180° from each other. The main parts of the tool include centering springs 20 which maintain the tool positioned in the center of well pipe 10, slips 21 which hold the tool in a stationary position, and the movable milling section 22 of the tool which carries the milling blades 23 used to mill grooves 25 (see FIG. 3) or make cuts 25a (see FIG. 3A) in well pipe 10. The extension rod 24 allows milling section 22 to move upwardly and downwardly relative to the stationary slip portion of the tool in order to cut the grooves or openings in well pipe 10 adjacent formation 15.

Once the grooves or cuts have been made in well pipe 10, tool 13 is removed from the well pipe and an explosive charge 30 is lowered on an electrical conductor type cable 31 to adjacent the weakened portion of the well pipe where the charge is detonated by means of an electrical charge transmitted through cable 31.

The results of exploding charge 30 are seen in FIG. 4. Well casing pipe 10 has ruptured along the weakened portions to form two half cylinders and two fractures, 32 and 33. The casing halves are forced apart past their yield points. The expanded casing halves permanently prop the fractures formed in formation 15.

As seen in FIG. 5, fractures 32 and 33 are filled with a conventional fracturing fluid containing a propping agent. These materials may be pumped into the fractures after they are formed by the explosive or they may be forced into the fracture at the time the fractures are created. The use of a fracture fluid, with or without a propping agent, is an optional procedure dependent upon the need for such treatment with any particular formation.

The explosive technique to be described with regard to FIGS. 6 to 9 for weakening the well pipe along the two, spaced-apart lines is preferred over the technique for weakening the well pipe just described in which a milling tool or other cutting means is used.

One design of a suitable combination tool for explosively weakening and expanding the well pipe is shown in FIGS. 6 and 7. A flat mandrel 35, provided with a peripheral groove 36 along its side and lower edges is suspended in a well pipe 37 from an electrical conductor cable 38. An explosive cord such as primer cord 39 is connected at one end to an ignition housing 40, to which cable 38 also is connected, and is threaded about the periphery of mandrel 35 in groove 36. The primer cord is then wrapped about the center portion of mandrel 35 through openings 41 formed in the body thereof. Upon firing of the ignition in housing 40 through cable 38, primer cord 39 is ignited and the explosion of the primer cord in groove 36 causes the casing to split or weaken along the primer cord path. Weakening of well pipe 37 along these lines is then immediately followed by the casing forming charge explosion, which in this instance is the primer cord wrapped about the body of mandrel 35 through holes 41, but alternatively may be any high explosive. The forming charge forces the casing halves apart past their yield point thereby creating

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and permanently propping with the expanded casing pipe a fracture in the formation. A well pipe expanded in this manner is seen in FIG. 9.

Another combination tool suitable for explosively weakening and expanding the well pipe is seen in FIG. 8. This tool includes an ignition housing 45 suspended from an electrical conductor cable 46 and a jet carrier bracket 47 containing aligned jet-shaped charges 48 surrounding and connected to a mandrel 49 secured to the ignition housing 45. Primer cord 50 leads from the ignition housing 45 and is connected to each series of aligned jets 48 and then to more primer cord or other high explosive wrapped about mandrel 49. This arrangement operates in a manner similar to the arrangement shown in FIGS. 6 and 7 and the results are the same as those illustrated in FIG. 9. The primer cord is fired by the ignitor in the ignition housing 45 set off by a signal through cable 46 which causes the series of jets 48 to first fire and weaken the casing after which the casing forming charge (the primer cord wrapped on mandrel 49) explodes to force the well pipe halves apart and to permanently prop with the expanded well pipe the fracture in the formation.

Thus, as shown, weakening of the well pipe may be accomplished by penetrating the well pipe with a number of closely spaced, axially aligned bullets or shaped charges, or with linear-shaped explosives, or by exploding primer cord or other high explosives near the well pipe wall. The mandrels used to hold the bullets or jets may be made of steel and be recoverable or they may be made of aluminum, glass or other expendable material.

Tensile strength of the formation is generally far less than compressive strength; hence, movement of the well pipe will create tensile failure in fracture rather than cause crushing of the formation. Once the radial stress of the well pipe exceeds its yield, the pipe will be permanently deformed and then will itself permanently prop open the fracture. As mentioned previously, this procedure may be accompanied or followed, if desired, by pumping sand or other propping material into the open fracture to extend the fracture and/or further support it by techniques well known in the art. Also, if necessary, the well pipe may be further supported internally in order to maintain the two half cylinders of well pipe separated and in the fracture mouth.

Having fully described the method, apparatus, objects, and advantages of my invention, I claim:

1. A method of fracturing subsurface formations penetrated by a well bore containing a generally cylindrical well pipe comprising the steps of forcing apart two half cylinders of said well pipe along a vertical section thereof adjacent a formation it is desired to fracture to prop open a vertical fracture formed in said formation.

2. A method of fracturing subsurface formations penetrated by a well bore containing a generally cylindrical well pipe comprising the steps of:

weakening said well pipe axially along two lines spaced approximately 180° from each other through the formation to be fractured; and

then explosively forcing apart said two half cylinders of said well pipe defined by said weakened well pipe lines to deform said well pipe halves past their yield points creating and permanently propping with said expanded well pipe a fracture in said formation.

3. A method as recited in claim 2 in which said well pipe is explosively weakened.

4. A method as recited in claim 2 in which said well pipe is mechanically weakened.

5. A method as recited in claim 2 in which a liquid

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containing propping material is pumped into said formation fracture.

6. Apparatus adapted to form a fracture in a subsurface formation and prop open the mouth of said fracture comprising:

a generally cylindrical well pipe penetrating said formation to be fractured;

a mandrel suspended from an electrical conductor cable in said well pipe adjacent said formation;

first explosive means arranged on said mandrel capable of weakening said well pipe axially along two lines spaced approximately 180° from each other upon detonation thereof;

second explosive means for forcing apart well pipe halves defined by said two lines past their yield point to create and permanently prop with said expanded well pipe a fracture in said formation upon detonation thereof; and

means for detonating said first and second explosive means.

7. Apparatus adapted to form a fracture in a subsurface formation and prop open the mouth of said fracture comprising:

a generally cylindrical well pipe penetrating said formation to be fractured;

first explosive means arranged in said well pipe adjacent said formation capable of weakening said well pipe axially along lines spaced from each other upon detonation thereof;

second explosive means arranged in said well pipe adjacent said formation for forcing apart portions of said well pipe defined by said lines past their yield point to create and permanently prop with said expanded well pipe a fracture in said formation upon detonation thereof; and

means for detonating said first and second explosive means.

8. Apparatus adapted to form a fracture in a subsurface formation and prop open the mouth of said fracture comprising:

a well pipe penetrating said formation to be fractured;

means arranged in said well pipe adjacent said formation capable of weakening said well pipe axially along two lines spaced approximately 180° from each other;

explosive means arranged in said well pipe adjacent said formation for forcing apart well pipe halves defined by said two lines past their yield point to create and permanently prop with said expanded well pipe a fracture in said formation upon detonation thereof;

means for actuating said well pipe weakening means; and

means for detonating said explosive means.

9. Apparatus as recited in claim 8 wherein said well pipe weakening means comprises explosive means.

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JACOB L. NACKENOFF, *Primary Examiner*.

CHARLES E. O'CONNELL, *Examiner*.

D. H. BROWN, *Assistant Examiner*.