Sept. 13, 1960 J. L. POPHAM 2,952,319

METHOD OF VERTICALLY FRACTURING CASED WELLS

Filed June 25, 1956 3 Sheets-Sheet 1

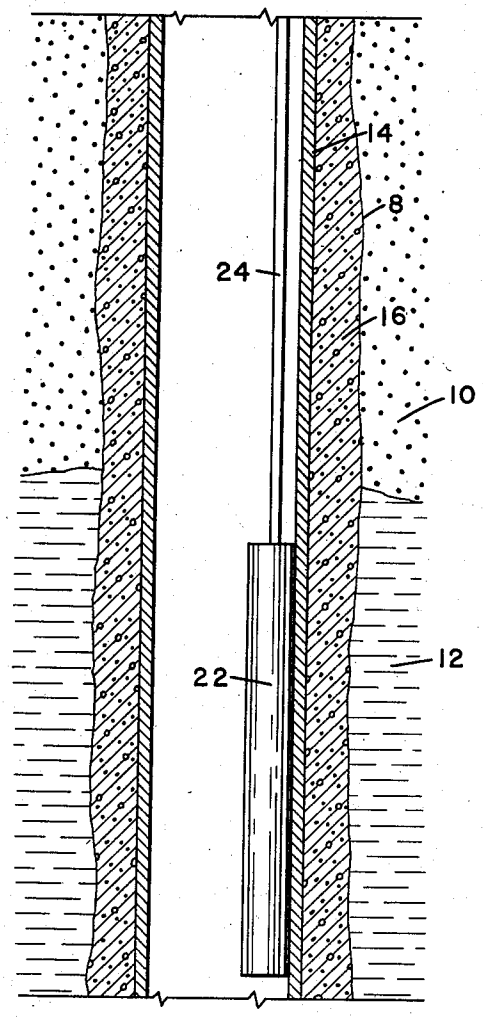


FIG. 1

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3 Sheets-Sheet 2

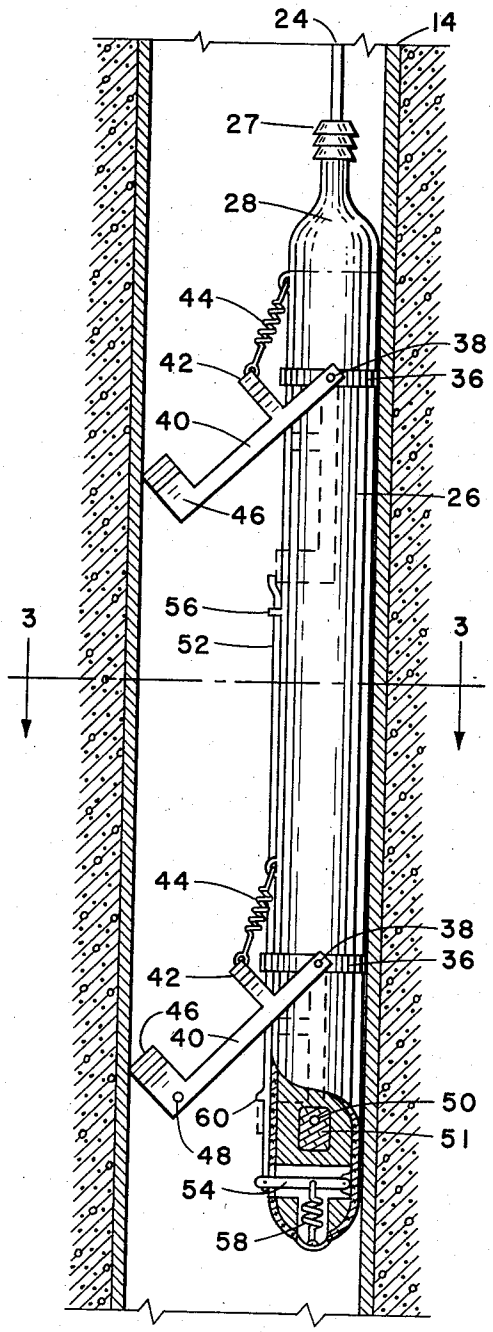


FIG. 2

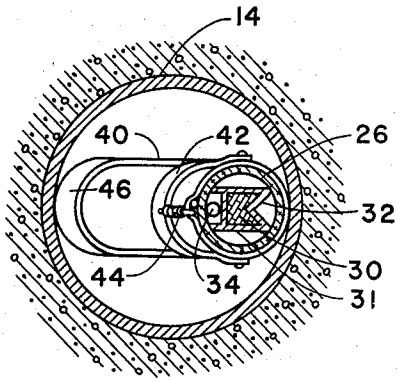


FIG. 3

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Filed June 25, 1956 3 Sheets-Sheet 3

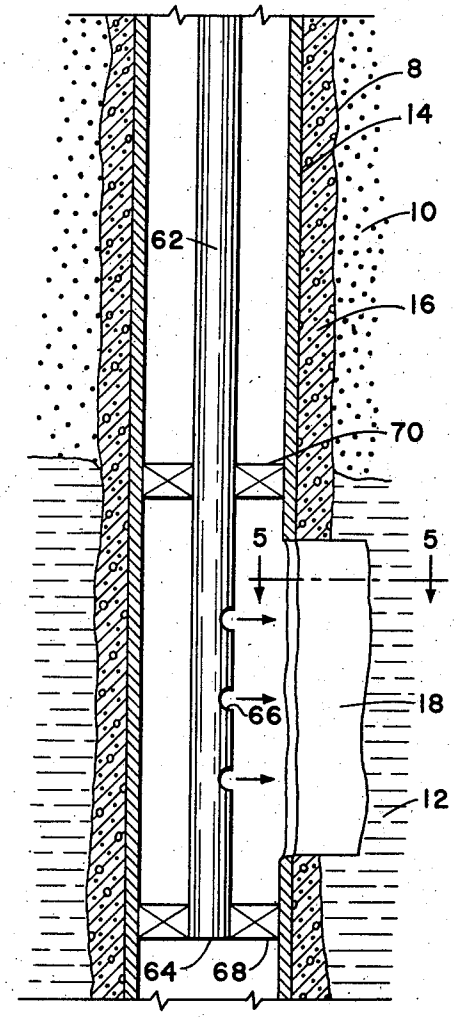


FIG. 4

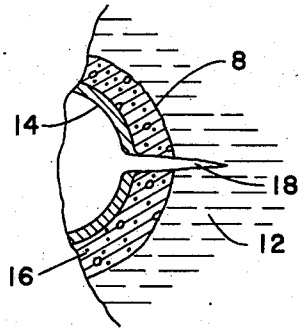


FIG. 5

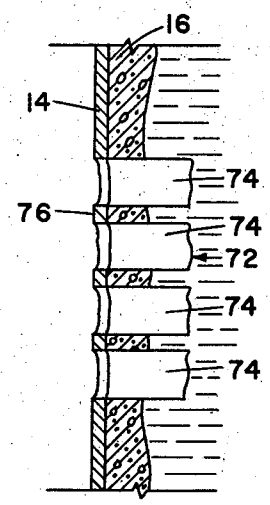


FIG. 6

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2,952,319

METHOD OF VERTICALLY FRACTURING CASED WELLS

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Filed June 25, 1956, Ser. No. 593,644

7 Claims. (Cl. 166—35)

This invention relates to improvements in the art of fracturing oil and gas wells, and more particularly to an improved method of vertically fracturing a completed well in which a casing has been set.

As it is well known in the petroleum producing industry, hydraulic fracturing of wells is used extensively for increasing the production of producing wells, and increasing the injection rates of water injection wells used in water disposal and secondary recovery operations. Generally speaking, and particularly in producing wells, vertically extending fractures have been found to be the most beneficial. However, procedures of forming vertical fractures demand that the portion of a well bore in which the fractures are created be uncased. That is, the well bore is open at the level where the fracture is created to expose the formation all the way around the periphery of the well bore.

Only limited fracturing is attempted in cased sections of wells at the present time. During completion of oil wells, a formation is infrequently fractured behind a perforated section of the casing. However, the size, generally circular shape and rather limited distribution of the perforations limits the area of the formation contacted by the fracturing fluid, and usually results in the creation of horizontal fractures.

A rather recent development in the art of fracturing behind casings is shown in U.S. Patent No. 2,642,142 issued to Joseph B. Clark on June 16, 1953. This patent teaches the use of weakened sections in casings, through which a fracturing fluid may be forced to contact and fracture a formation behind the weakened section. According to this patent, selected portions of a casing are weakened, as by reducing the wall thickness of the casing or inserting a weak metal in the casing wall, prior to setting the casing in a well. It will, therefore, be apparent that such a method may be used only in new wells (as contrasted with old wells which have already been cased in the usual manner). Also, a substantial tension is placed on a casing as it is being lowered in a well, therefore the weakened sections of the casing must necessarily be limited in size to prevent parting of the casing during the lowering operation.

The present invention contemplates a novel method of fracturing wells which have been cased in such a manner as to assure the creation of vertical fractures. In accordance with this invention, a slot is formed through the casing and the usual cement sheath surrounding the casing at the desired height or level in the well. The slot is of such a size as to expose a sufficient area of the formation that when a low fluid loss fracturing fluid is forced through the slot, the formation will be vertically fractured. This invention also contemplates the extension of the slot into the formation proper, to further assure the creation of a vertical fracture. It will be observed that by the use of this method, the casing will not be weakened prior to the fracturing operation, and the method is particularly applicable to old wells which have been in service for some time.

An important object of this invention is to increase the efficiency of wells, and particularly wells which have been in service for some time.

Another object of this invention is to provide a method of creating vertical fractures behind the casing of a well.

A further object of this invention is to provide a method of fracturing cased wells, wherein the casing is not weakened before the fracturing operation, and wherein the casing is weakened to a limited degree by the fracturing operation.

Another object of this invention is to provide a method of fracturing a formation around a well at any desired level in the well.

A still further object of this invention is to provide a simple method of fracturing wells which may be economically performed.

Further objects and advantages of the invention will be evident from the following detailed description, when read in conjunction with the accompanying drawings which illustrate my invention.

In the drawings:

Figure 1 is a vertical sectional view through a portion of a typical well illustrating the positioning of a slitting tool in the well in accordance with this invention.

Figure 2 is a side elevational view of a suitable slitting tool which may be used in practicing this invention, illustrating the positioning of the tool in a well casing.

Figure 3 is a sectional view taken substantially along lines 3—3 of Fig. 2.

Figure 4 is another vertical sectional view through the well illustrated in Fig. 1 showing other necessary apparatus for carrying out the method of this invention.

Figure 5 is a sectional view taken substantially along lines 5—5 of Fig. 4.

Figure 6 is a partial sectional view taken vertically through a portion of a well and casing illustrating a modified type of slot.

Broadly stated, the present invention may be defined as a method of vertically fracturing a subsurface formation traversed by a vertical well bore, wherein the well bore has a casing therein and the casing is cemented through said formation, comprising the steps of:

(*a*) Forming a vertical slot through the casing and cement into said formation, and then

(*b*) Forcing a low fluid loss fracturing fluid outwardly through said slot under sufficient pressure to fracture said formation.

Referring to the drawings in detail, and particularly Fig. 1, reference character **8** designates a well bore which extends vertically through a plurality of subsurface formations. For simplicity, I have shown only two of the subsurface formations **10** and **12**. A well casing **14** extends downwardly through the well bore **8** and a cement sheath **16** surrounds the casing **14** throughout the formations **10** and **12**. It will be understood by those skilled in the art that the cement sheath **16** is formed after the casing **14** has been placed in the well bore **8**, and that the cement sheath **16** ordinarily extends throughout the potentially producing formations.

In accordance with this invention, any of the usual perforations (not shown) extending through the walls of the casing **14** and the cement sheath **16** are closed-off or plugged by any suitable means such as the usual technique of squeeze cementing. Such perforations are ordinarily provided to facilitate the drainage of formation fluids into the casing **14**, and are provided at the various potential producing horizons. However, only those perforations at, and in the vicinity of, the level at which the formation is to be fractured need be closed-off or plugged.

Assuming it is desired to create a vertical fracture in the formation **12**, the casing **14** and cement sheath **16**

are first slotted, as shown at 18 in Figs. 4 and 5. It will be observed that the slot 18 extends vertically along the axis of the casing 14, and preferably extends into the formation 12. Also, the slot 18 should not cross the couplings (not shown) of the casing 14, since this would unduly weaken the casing. The slot 18 should be from 4 to 16 feet in length and about ⅛ to ½ inch wide, to assure the creation of a vertical fracture in the formation 12, as will be more fully hereinafter set forth.

To slit the casing 14 and cement sheath 16, a suitable slitting tool 22 is lowered to the desired position opposite the formation 12 as illustrated in Fig. 1. The tool 22 may be lowered by use of a cable 24 extending from the mouth of the well bore 8, with the cable 24 being passed over a measuring reel or the like (not shown) to indicate the level of the tool 22. When the tool 22 is in the proper position, it is actuated to form the slot 18, and may then be withdrawn from the well. As previously indicated, it is preferred that the slitting tool 22 be of a type which will extend the slot 18 through the casing 14 and cement sheath 16 into the formation 12 proper.

One type of tool which may be used is schematically shown in Fig. 2, and comprises a hollow housing 26 formed out of a light-weight frangible metal, such as aluminum. The housing 26 is suitably suspended from the cable 24 through use of a cable connector 27 and head member 28. When using this type of slitting tool, the cable 24 is of the type used in well logging operations, whereby electrical signals may be sent to the tool from the mouth of the well for actuating the tool, as will more fully hereinafter appear. The head 28 also contains a suitable firing mechanism (not shown) of the type normally used in perforating guns, with the firing mechanism connected to the circuitry in the cable 24.

As shown in Fig. 3, the housing 26 contains an elongated explosive charge 30 supported by a framework 31 and having one side 32 thereof shaped in the form of a cone or V (when viewed in a horizontal cross-section), whereby the energy created by the explosive charge will be directed along a vertical plane through the wall of the housing 26. A suitable fuse 34, such as primacord, extends downwardly from the firing mechanism in the head 28 through the housing 26 along the side of the explosive 30 opposite the shaped side 32 to detonate the explosive upon actuation of the firing mechanism in the head 28. The explosive charge 30 will, of course, be of a length corresponding to the desired length of the completed slot 18.

A pair of supporting bands 36 are secured in vertically spaced relation around the housing 26, and each band 36 has a pair of outwardly extending pins 38 for supporting a U-shaped bracket 40. A curved strap 42 extends between the opposite arms of each bracket 40 to receive the lower end of a helical tension spring 44. The upper end of each spring 44 is in turn anchored to the housing 26, whereby the brackets 40 are constantly urged in a clock-wise direction into their open positions as illustrated by the full lines in Fig. 2. It will also be noted that each strap 42 is curved on the arc of a circle corresponding to the periphery of the housing 26, whereby the arms of the brackets 40 may be positioned on opposite sides of the housing 26 when the brackets 40 are pivoted to their closed positions as indicated by the broken lines in Fig. 2. The lower or outer end 46 of each bracket 40 is shaped in the same manner as the respective strap 42.

The lower bracket 40 has an aperture 48 extending transversely through the lower end thereof to receive a shear pin 50 projecting from the side of the housing 26. The shear pin 50 retains the lower bracket 40 in a closed position on the housing 26 when the tool is being lowered into a well bore. A suitable auxiliary explosive charge 51 is associated with the shear pin 50 and is wired (not shown) to the firing mechanism in the head 28 by a circuit separate from that which actuates the fuse 34, whereby the shear pin 50 may be sheared or blown out of the housing 26 to release the lower bracket 40 prior to detonation of the main explosive charge 30.

The upper bracket 40 is retained in a closed position by the upper end of a release wire 52 which extends down along the outside of the housing 26 to a pivot arm 54 secured on the lower end portion of the housing 26. The release wire 52 is slidably secured to the housing 26 by one or more guides 56 to retain the wire 52 in a vertical position along the side of the housing 26. A tension spring 58 is secured to the pivot arm 54 to constantly urge the arm 54 in a counter clock-wise or downward direction, and a projection 60 is formed on the release wire 52 immediately above the lower end 46 of the lower bracket 40 when the lower bracket is in a closed position over the housing 26. It will be apparent that the projection 60 contacts the end 46 of the lower bracket 40 when the lower bracket is in a closed position to prevent pivoting of the arm 54 and a consequent release of the upper bracket 40. However, when the shear pin 50 is broken, and the lower bracket 40 released to spring into its open position, the pivot arm 54 is freed and pivots in a counter clock-wise direction to lower the release wire 52 and free the upper bracket 40. Whereupon, both of the brackets 40 are pivoted to their open positions, to bring the lower ends 46 of the brackets into contact with one side of the casing 14. The brackets 40 will thus urge the housing 26 to the opposite side of the casing 14 and position the shaped side 32 of the main explosive charge 30 parallel to the axis of the casing 14 and into proximity with one side of the casing.

The main explosive charge 30 is then detonated and the resulting explosive blast creates the slot 18 extending through the casing 14 and the cement sheath 16 into the formation 12. During detonation of the main explosive charge 30, the housing 26 and all parts of the apparatus below the head 28 will be disintegrated, or at least blown apart, thereby leaving only the head 28 suspended in the casing 14 on the lower end of the cable 24. It is preferred to salvage the head 28, since the firing mechanism contained therein is usually the most expensive portion of the slitting apparatus. The head 28 is then removed from the well by raising the cable 24.

A string of tubing 62 (see Fig. 4), having its lower end 64 closed and one or more perforations 66 slightly above the end 64, is then run in the casing 14 to a point slightly below the slot 18. A packer 68 of any suitable type is set between the lower end 64 of the tubing 62 and the inner periphery of the casing 14 immediately below the slot 18. Another packer 70 is set on the tubing string 62 in the casing 14 immediately above the slot 18 and above the perforations 66 to effectively pack-off that portion of the casing 14 which includes the slot 18.

A low fluid loss fracturing fluid is then pumped down through the tubing string 62 and discharged through the apertures 66 into the casing 14 between the packers 68 and 70 As the pressure of the fracturing fluid is increased, the pressure is exerted outwardly through the slot 18 into contact with the formation 12 Since the fracturing fluid will have a minimum tendency to filter into the formation 12, a pressure zone is created against the face of the formation 12 which corresponds to the cross-sectional area of the slot 18. When the pressure of the fracturing fluid reaches the rupture pressure of the formation, a vertical fracture (not shown) will be created in the formation 12. Upon the creation of the fracture, a suitable propping material, such as sand, may be pumped down through the tubing string 62 along with an additional supply of fracturing fluid to extend the fracture and force the propping material into the fracture. When the pressure of the fluid in the tubing 62 is subsequently reduced, the fluid will tend to drain out of the fracture back through the slot 18 into the casing 14, and at least a portion of the propping material will be deposited in the fracture to retain the fracture open, as it

is well known in the art. The tubing **62** and the packers **68** and **70** are then removed from the casing **14** and the well may be placed on production to resume normal operations.

As previously indicated, it is preferred that the fracturing fluid being used be a low fluid loss fracturing fluid. The specific type of fracturing fluid is not critical, since either a viscous or relatively non-viscous fluid may be used, depending upon the desires of the operator. However, the face of the formation **12** opposite the slot **18** must be sealed against substantial fluid leakage into the formation before there is assurance that a vertical fracture will be formed. Such sealing is preferably accomplished by first filling the slot **18**, and that portion of the casing **14** between the packers **68** and **70**, with a fracturing fluid (usually oil) containing suitable low fluid loss materials, such as asphalt or ground nut shells. Any suitable pressuring fluid is then pumped down the tubing **62** to increase the pressure of the fracturing fluid. As this pressure is increased, a portion of the fracturing fluid will be forced into the formation **12** and a portion of the low fluid loss materials will deposit on the face of the formation in the form of a sheath or cake to gradually reduce the loss of the fracturing fluid to the formation.

It is preferred that the pressure of the fracturing fluid be increased step-wise, with the surface pressure being held constant for a short time, say 15 minutes, at progressively increasing values below the rupture pressure of the formation **12**. In this technique, pressuring fluid is pumped into the tubing **62** until a desired pressure is reached, and then the pumping is stopped and the rate of pressure decline is observed. This rate of pressure decline is a direct indication of the amount of fracturing fluid being lost to the formation **12**. More fluid is then pumped into the tubing **62** until a higher pressure is reached, and the rate of pressure decline is again observed. This operation is repeated until a sheath of the desired fluid impermeability has been built on the face of the formation **12**. When the rate of pressure decline is about 50 p.s.i.g. in one hour at a surface pressure of 1,000 p.s.i.g., it may be assumed that a sufficiently fluid impermeable sheath has been formed on the formation **12**. Pressuring fluid is then pumped into the tubing **62** at an accelerated rate and the pressure of the fracturing fluid increased until the formation is fractured. The sheath formed on the face of the formation **12** confines the pressure to the face of the formation, rather than into the formation, and facilitates the formation of a vertical fracture. The occurrence of the fracture will normally be accompanied by a sharp decline in surface pressure.

As an alternate to the step-wise procedure discussed above, the pressure of the fracturing fluid may be increased gradually until the desired sheath has been built on the face of the formation **12**. However, caution must be used to prevent an increase of pressure to above the rupture pressure of the formation before the sheath is built, since during this period the pressure of the fracturing fluid will be exerted within the formation and a horizontal fracture may occur.

As to fluid loss properties, it is preferred that the fracturing fluid have a fluid loss at least as low as 10 ccs. when tested by the Standard Field Procedure for Testing Drilling Fluids, section IV, API Test RP29, May 1950. However, the required fluid loss properties may be varied, depending upon the type of formation being fractured.

In lieu of the continuous slot **18**, this invention also contemplates the utilization of a discontinuous slot, as indicated generally at **72** in Fig. 6. Such a discontinuous slot **72** comprises vertically spaced portions **74**, with each portion **74** being of a length from six inches to four feet, and the spacing between the portions **74** being about one or two inches. The overall length of the slot **72** may be from four to sixteen feet. Such a slot leaves spaced straps or bands **76** in the wall of the casing **14** between the portions **74** to strengthen the casing **14** and minimize the possibility of collapse of the casing after completion of the fracturing operation.

When a fracturing fluid is forced under pressure through the portions **74** of the slot **72**, the resulting pressure zone on the face of the formation being fractured will be substantially continuous, and a sufficient height of the formation will be contacted to result in a vertical fracture. It will be apparent that such a discontinuous slot may be formed with a tool of the type illustrated in Figs. 2 and 3 and previously described, with the main explosive charge **30** being formed in vertically spaced sections, whereby the casing **14** will be slotted at vertically spaced intervals upon detonation of the explosive charge.

In addition to the above, it is also preferred that the slot **18** (or the discontinuous slot **72**) be extended, not only through the casing **14** and the cement sheath **16**, but also into the formation **12** proper. Thus, fracturing fluid forced through the slot will contact a greater area of the formation and facilitate the creation of a vertical fracture.

From the foregoing it is apparent that the present invention will increase the efficiency of wells, and particularly wells which have been in service for some time. The invention provides a novel method of creating vertical fractures behind the casing of wells and the casing is not weakened before the fracturing operations. A vertical fracture may be formed at any desired level in a well, and the method may be economically performed.

Changes may be made in the combination and arrangement of steps as heretofore set forth in the specification and illustrated in the drawings without departing from the spirit and scope of the invention as set forth in the appended claims.

I claim:

1. A method of vertically fracturing a subsurface formation traversed by a vertical well bore, provided with a casing cemented therein, comprising the steps of:

(*a*) forming a vertical slot through the casing and cement into said formation by inserting a tool into the cased well bore having a vertically elongated unidirectional explosive charge aligned with the longitudinal axis of said tool and placing said tool in the immediate proximity of the well bore casing, with the shaped side of said charge facing said proximate casing exploding said charge,

(*b*) forcing a low fluid loss fracturing fluid outwardly through said slot under insufficient pressure to fracture the formation to form a substantially fluid impermeable sheath on the face of the exposed formation, and then

(*c*) increasing the pressure of said fracturing fluid until the formation is vertically fractured.

2. A method of vertically fracturing a subsurface formation traversed by a vertical well bore, provided with a casing cemented therein, comprising the steps of:

(*a*) forming a vertical slot through the casing and cement into said formation by inserting a tool into the cased well bore having a vertically elongated unidirectional explosive charge aligned with the longitudinal axis of the tool and placing said tool in the immediate proximity of the well bore casing with the shaped side of said charge facing said proximate casing by urging means, exploding said charge,

(*b*) forcing a low fluid loss fracturing fluid outwardly through said slot under pressure insufficient to fracture said formation to form a substantially fluid impermeable sheath over the exposed formation face, and then

(*c*) forcing a fracturing fluid outwardly through said slot against said sheath under sufficient pressure to vertically fracture the formation.

3. A method of vertically fracturing a subsurface formation according to claim 1 wherein the tool in step (*a*) is placed against the well bore casing with the shaped side of said charge facing the adjoining casing.

4. A method of vertically fracturing a subsurface formation according to claim 3 wherein the pressure in step (*b*) is maintained at a level insufficient to fracture said formation until the sheath formed on the formation face reduces fluid loss to at least as low as 50 p.s.i.g. in one hour at a surface pressure of 1,000 p.s.i.g.

5. A method of vertically fracturing a subsurface formation according to claim 4 wherein the pressure of step (*c*) is increased at an accelerated rate until said formation is vertically fractured.

6. A method of vertically fracturing a subsurface formation according to claim 5 wherein the fracturing fluid of step (*b*) has a fluid loss at least as low as 10 cc. when tested by the Standard Field Procedure for Testing Drilling Fluids, section IV, API Test RP29, May 1950.

7. A method of vertically fracturing a subsurface formation according to claim 2 wherein in step (*a*) the tool is frangible and is placed against said casing with the shaped side of said charge facing the adjoining casing whereby said charge is placed into proximity of the well bore casing.

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