June 30, 1970 G. O. SUMAN, JR 3,517,745

WELL PERFORATING METHOD

Filed June 20, 1968 2 Sheets-Sheet 1

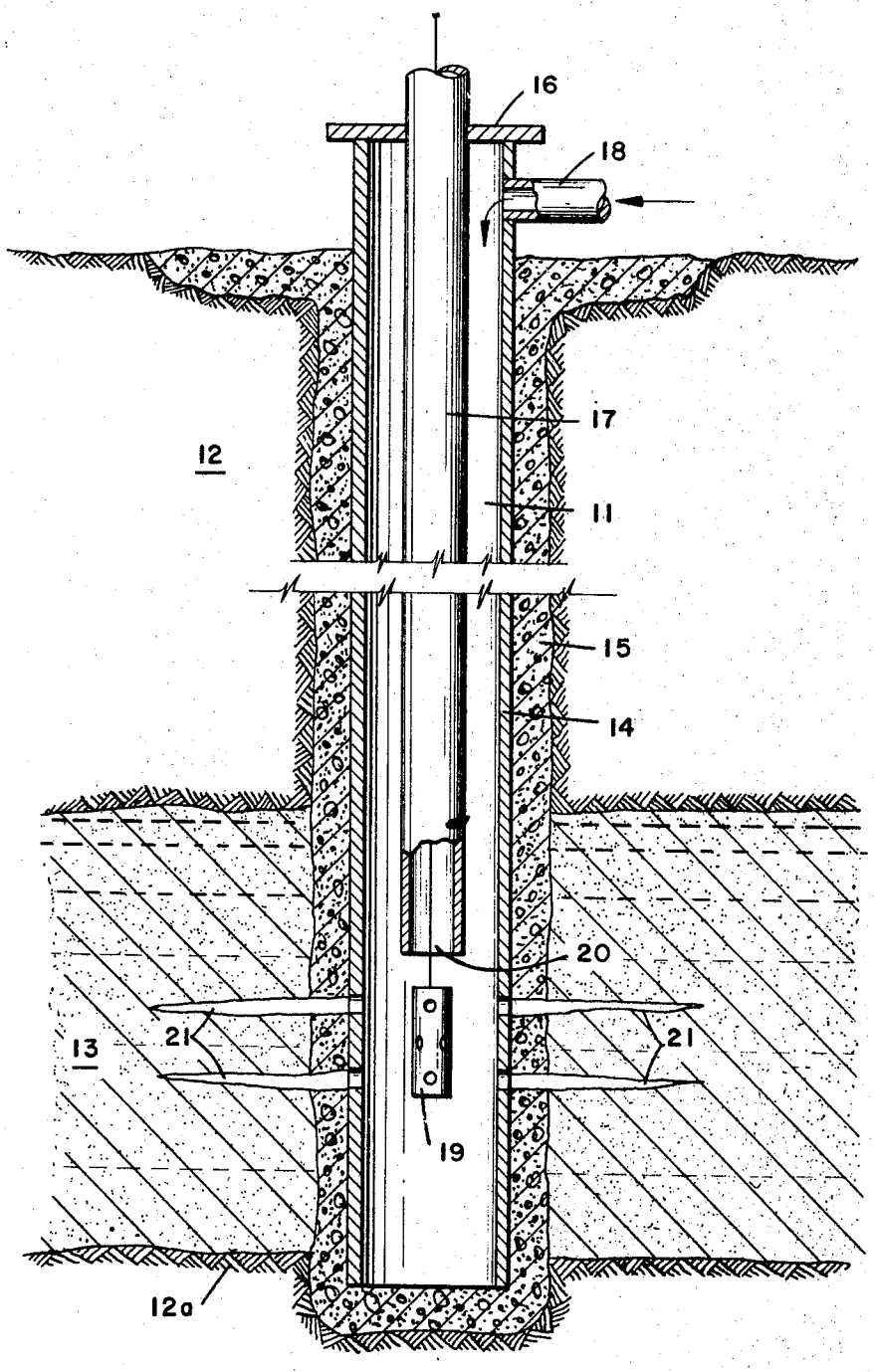


FIG. 1

INVENTOR:
GEORGE O. SUMAN, JR.
BY: Louis J. Bovasso
HIS ATTORNEY

June 30, 1970 G. O. SUMAN, JR 3,517,745

WELL PERFORATING METHOD

Filed June 20, 1968 2 Sheets-Sheet 2

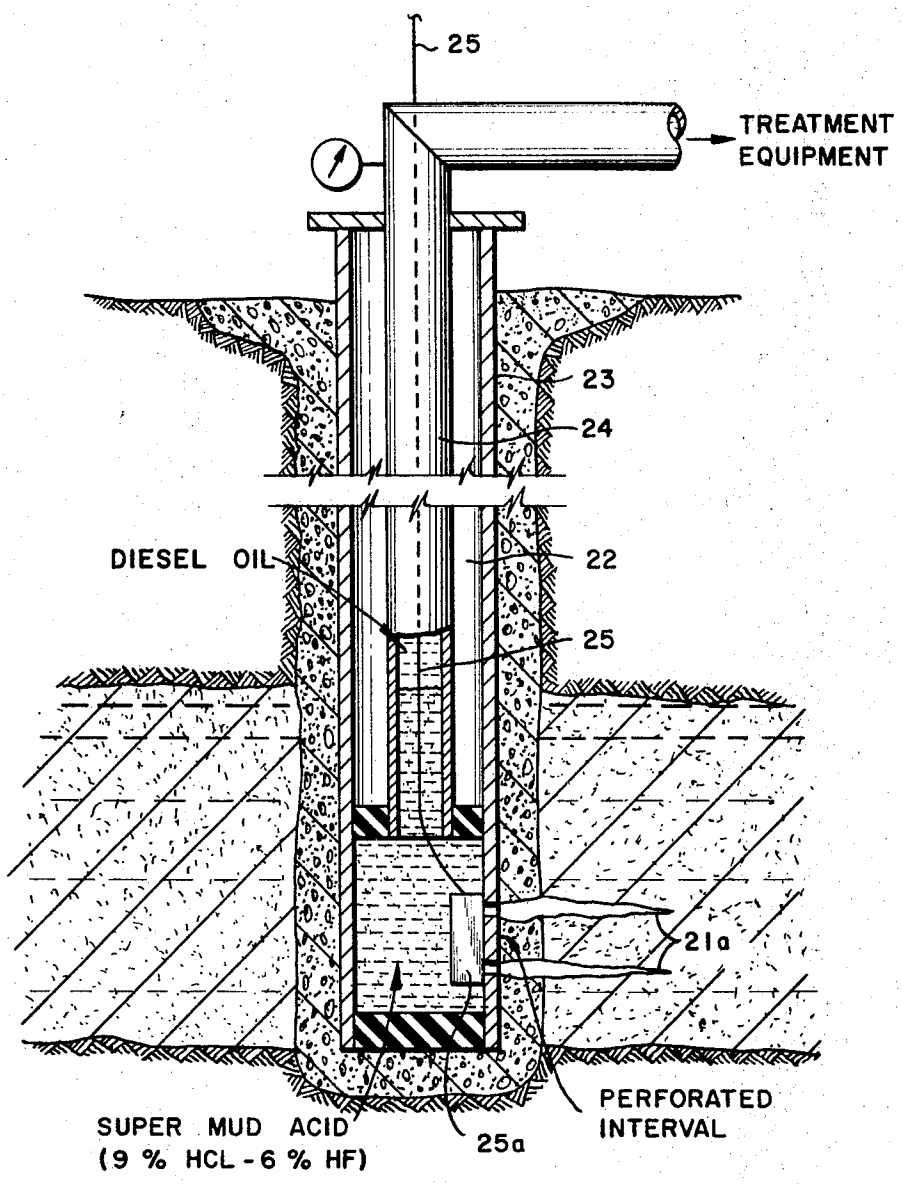


FIG. 2

INVENTOR:
GEORGE O. SUMAN, JR.
BY: Louis J. Bovasso
HIS ATTORNEY

United States Patent Office 3,517,745 Patented June 30, 1970

3,517,745

WELL PERFORATING METHOD

George O. Suman, Jr., Metairie, La., assignor to Shell Oil Company, New York, N.Y., a corporation of Delaware

Filed June 20, 1968, Ser. No. 738,530
Int. Cl. E21b 43/25
U.S. Cl. 166—297 6 Claims

ABSTRACT OF THE DISCLOSURE

A method of perforating a well casing extending into communication with a subterranean hydrocarbon-bearing formation having an interval portion adjacent the formation by introducing a fluid into a restricted zone of the well casing and adjacent the interval portion under controlled pressure conditions raising the pressure of the fluid to a pressure at least sufficient to drive the fluid out of the well casing and into the formation upon perforation of the casing and perforating the casing and adjacent interval portion so as to force the fluid through the established perforations and into the hydrocarbon-bearing portion of the formation.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to a method for producing perforations in solid materials and more particularly to a method for creating such perforations in wells and earth formations penetrated by a well borehole.

Description of the prior art

In many types of wells, such as oil or gas wells, for example, a casing is placed in the well borehole, and the casing is then perforated in the vicinity of selected producing zones in the surrounding earth formation to thereby condition the well for production operations. In the forming of such perforations, the resulting cavities desirably extent not only through the well casing but also through the surrounding cement and a portion of the adjacent earth formation. As an illustration, it often is advantageous to fracture the earth formation adjacent the producing zones, such as by hydraulic means, for example, in order to increase the permeability of the formation, and the cavities greatly facilitate the fracturing operation.

Various methods and apparatus have been used heretofore in the perforation of a well casing and/or a selected earth formation in a well borehole. Thus, in some cases, the perforations have been produced mechanically and have also been formed through the use of explosive means, such as a jet or bullet perforating gun.

Prior to perforating a casing or formation with suitable devices, e.g., guns, a sheath is placed around the casing. This may be a cement sheath or formation material surrounding the well borehole and particularly around the part to be perforated. These materials pulverized by the perforating device consist of sand, clay, cement, limestone, dolomite, etc. in conjunction with mud particles and/or clay dispersed by mud or cement filtrate, which are believed to plug the perforations. These materials subsequently cause plugging of the formation which materials must be removed prior to conducting other completion operations and/or placing the well on production. This is a relatively time-consuming and expensive process.

SUMMARY OF THE INVENTION

It is an object of this invention to provide an improved method for perforating well formations.

It is a further object of this invention to perforate well formations while maintaining well control from the time of perforating to conducting subsequent operations with solids-free fluids in the well.

It is a still further object of this invention to provide a well perforating method in which substantially all of the perforation-plugging agents generally surrounding the areas being perforated are removed by high pressure flushing and/or chemical means during the perforating step.

These objects are preferably carried out by introducing a fluid under controlled pressure through the well into a subterranean hydrocarbon-bearing formation opposite and adjacent the interval to be perforated. The fluid is preferably adapted to remove at least some of the plugging material in the interval portion of the formation. A perforating device is lowered into the interval portion and the pressure of the fluid is raised to a pressure at least sufficient to drive the fluid out of the well and into the formation. Not only is the interval portion perforated, but the pressurized fluid is driven out of the well through the perforations while removing some or all of the impairment material surrounding the perforations.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical sectional view of a preferred method for carrying out the concepts of the invention; and

FIG. 2 is a vertical sectional, partly schematic view of an example of the method of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1 of the drawing, there is shown a well bore-hole **11** extending through overlying earth formation **12** into communiction with a subterranean hydrocarbon-bearing formation **13**. The hydrocarbon-bearing production zone is confined by lower layer **12***a*. Well borehole **11** is preferably cased at casing **14** and cemented at **15** as is well known in the art. Casing **14** is closed at its upper end **16** and preferably includes a tubing string **17** extending therethrough into engagement with **13**. Tubing string **17**, however, is not necessary for carrying out the teachings of this invention. A fluid inlet **18**, disposed at the upper end of casing **14**, communicates with both an external fluid source (not shown) and the interior of well borehole **11**.

A perforating device **19** is illustrated in FIG. 1 as having been lowered, through suitable lowering means, such as a winch (not shown) and a cable **20**, through tubing string **17** into well borehole **11**. Besides being of sufficient strength to raise and lower perforating device **19** in well borehole **11**, cable **20** may include the necessary electrical, mechanical or hydraulic conduits for actuating device **19**. Perforating device **19** may be any suitable penetrating means, such as a jet or bullet perforator as is well known in the art. Perforators are generally of two types, both lowered into the well borehole on conductor cables and carrying explosive charges that are electrically detonated. In the "bullet perforator," steel bullets are fired through the casing and cement; in the "shaped charge perforator," small explosive charges are used, so shaped that the explosive force is focused and intensified into a small diameter jet which penetrates casing and cement.

In operation, an acid or other dissolving and/or chemically reactive fluid is preferably pumped into well borehole **11** through fluid inlet **18** or down tubing **17** above the formation **13** and surrounding the interval portion of well borehole **11** which interval portion includes the portions of casing **14**, cement **15** and formation **13** desired to be perforated. This fluid is adapted to dissolve and/or react with the material comprising the material of formation **13** and the interval material (that is, the

material comprising the cemented casing, etc.) or portions thereof. When used throughout the remainder of this specification, the "fluid" referred to, unless otherwise indicated, is a fluid adapted to remove the interval and formation materials (referred to as "impairment material"). The word "dissolve" or "dissolves" as used throughout this specification includes any chemical reaction or reactions adapted to break down or decompose materials such as various types of mud acids (i.e.) solutions of hydrochloric and hydrofluoric acids).

The pressure of the fluid is then raised, as by pumping from the surface through inlet **18**, so as to drive the fluid out through all of the perforations **21** when the perforating device **19** is actuated. Obviously, the number of perforations **21** depends on the extent of the interval to be perforated. The pressure of the fluid is raised to previously determined or estimated over-balance pressures which may, but not necessarily, be capable of fracturing the perforated material (i.e., the perforated formation **13**). The surface pressure of the fliud is thus raised and controlled by means well known in the art to provide an instantaneous surge of the active fluid into all perforations **21** at high differential pressures. An important feature of this application is considered to be the magnitude of the differential pressures involved. For maximum capability of forcing fluid into each perforation, the highest possible differential pressures are desired, limited only by mechanical equipment in use and pressures at which cement bonding can be destroyed or fractures generated (if fractures are not desired for the completion being effected). The use of relatively high surface pressures during the perforating operation is therefore a key to this procedure.

By perforating in the presence of such relatively high differential pressures and with the fluid in the well bore capable of removing the impairment material (i.e., the pulverized materials plugging the perforations **21** and any other material surrounding the perforations **21**), such plugging is reduced and/or substantially eliminated. The driving force of the fluid assures that sufficient fluid is driven into all the perforations; regardless of the restrictions to flow imposed by the plugging agents and/or normal permeability variations, thereby causing substantial removal of the plugging agents from most and/or all perforations. If the fluid is not adapted to dissolve such impairment material, the fluid is introduced at sufficiently high enough pressure to remove or flush such material away from the borehole **11**.

Since the step of perforating can be conducted through a tubing string as discussed hereinabove, well control can be maintained from the step of perforating through any necessary subsequent steps.

For example, with the tubing string **17** in place, after perforating, the perforating device **19** is removed and resin or plastic consolidation materials are pumped down the well through tubing string **17** and out through the perforations **21** thereby consolidating the sand of formation **13**. In poorly consolidated sand formations, sand may be carried into the well borehole with the oil and gas. This should be prevented, or at least kept to a minimum, to avoid plugging the well thereby stopping production and to lessen the wear of pumps, valves, liners, etc. The production of large quantities of sand alone or in combination with reservoir compaction can also cause damage to the casing of a well through casing deflection or "buckling." This loose sand may be consolidated by means of binding the sand grains without materially affecting the productivity of a well. Such plastic or resin consolidation materials and methods of consolidation include the epoxy resins manufactured by Shell Chemical Co. and the consolidation method described in U.S. Pats. 3,368,625; 3,368,626; and 3,339,633. Other types include phenol-formaldehyde resins and silicates etc. If sand exclusion is delayed until the formation has been disturbed by fluid movement or other factors, sand consolidation becomes more difficult and, in some cases, impossible. Trace amounts of solids in any of the pretreating fluids can prevent resins or plastics from entering one or more of the perforations, thus resulting in an unsuccessful treatment. As the perforating in accordance with the method of this invention is carried out in a clean fluid, it can be seen that the success of any subsequent sand consolidation treatment is greatly enhanced by this degree of cleanliness maintained in the well from the time of perforating through the time of plastic or resin placement in the unconsolidated formation.

Since the fluids present in the well utilizing the method of this invention and which would precede any well treatment following perforating are solid-free, no plugging occurs. Thus, from operation to operation, there is no plugging of the cleaned-out perforations **21**. Following sand consolidation or other treatments in which the need for unplugged perforations is imperative, fluids containing solids for fluid loss control (and/or suitable emulsions) may be injected through inlet **18**, into the annulus formed between tubing string **17** and casing **14** and well control maintained for later operations. Alternatively, the fluid loss control fluids and/or emulsions may be injected down tubing string **17** and into well borehole **11**.

As disclosed hereinabove, once the casing and formation has been perforated by the method of this invention, placement of plastic consolidation materials for control of sand is facilitated as well as making it possible for proper placement of cement during squeeze operations, open perforations prior to fracturing operations are ensured, more uniform distribution of stimulation treatments are assured and other well completion and workover operations are also made possible. For example, if some perforations are plugged, cement used in squeezing may not go out through them. In this case, a portion of the interval may not receive squeeze cement and a weakness in the job results. If some perforations are plugged, portions of the material will not be fractured nor otherwise stimulated.

EXAMPLE

The following is an example of through tubing perforating using a super mud acid mixture with a high overbalance pressure in a subterranean earth formation, followed immediately by a plastic consolidation treatment in accordance with the teachings of this invention and as described in the U.S. Pat. 3,339,633.

Overbalance perforating through tubing with acid spotted in the casing opposite the interval to be perforated and with high pressure imposed at the surface was conducted in a well. A surface pressure of 2,000 p.s.i. provided a 5150 p.s.i. bottom-hole pressure and a 3365 p.s.i. overbalance to drive the super mud acid out through all the perforations and into the reservoir (1785 p.s.i. static reservoir pressure). The formation was treated with epoxy resin as described in Example **1** of the above patent by conducting it through the tubing as placed for the perforating operation. See FIG. 2 where a well borehole **22** is shown having a casing **23** and tubing string **24** disposed therein. A wireline **25** extends through tubing **25** and includes a through tubing perforating gun **25***a* at its lower end. Gun **25***a* is of the carrier type side-kicked and is actuated forming perforations **21***a*.

At the time of firing, the tubing was full of diesel oil with the exception of several hundred feet of super mud acid at the bottom. Thus, the impairment problems associated with solids in the completion fluid were avoided. After retrieving the gun **25***a* (a $1\frac{11}{16}$-in. Jet Research Company Sidewinder gun), the epoxy resin composition for earth formation consolidation treatment was conducted immediately without moving the squeeze packer which was in the proper position for the epoxy resin treatment at the time of perforating. Injectivity was established with the diesel oil already in the tubing at

1 b.p.m. at 1300 p.s.i. surface pressure. A portion of the epoxy resin treatment was conducted on a vacuum due to a minor delay. Impairment appears to have been minimized as a result of the technique, and there has been no indication of sand production to date. Currently, the T sand is gas-lifting at daily rates in excess of 425 barrels of fluid with a water cut of 2 percent.

I claim as my invention:

1. A method of perforating a well extending into a subterranean hydrocarbon-bearing formation adjacent an interval portion thereof comprising the steps of:

introducing a fluid under controlled pressure into the well adjacent said interval portion thereof, said fluid being adapted to remove at least some of the material in said formation interval portion;

lowering a perforating device into said fluid in said well adjacent said formation interval portion desired to be perforated;

raising the pressure of said fluid to a pressure at least sufficient to drive said fluid out of said well and into said formation interval portion upon perforation but insufficient to fracture said formation; and

perforating said formation interval portion via said perforating device to remove at least some of the impairment material surrounding said perforations by driving said pressurized fluid out of the well through the perforations formed in said formation interval formation by said perforating device without fracturing said formation interval portion.

2. The method of claim 1 including the step of extending a tubing string into said well prior to introducing said fluid therein thereby forming an annulus between said string and said well; and introducing said fluid into the well through said tubing string.

3. The method of claim 2 including the step of injecting a fluid loss control fluid down the annulus formed between said tubing string and said well behind said removal fluid.

4. The method of claim 1 wherein the step of introducing a fluid adapted to remove at least some of the material in said formation interval portion includes the step of introducing a fluid adapted to subsequently chemically react with said impairment material to thereby dissolve said impairment material.

5. The method of claim 1 including the step of injecting a fluid loss control fluid down said well behind said removal fluid.

6. The method of claim 1 including the step of injecting sand consolidating materials into said well adapted to consolidate any loose sand within the formation interval portion adjacent said perforations.

References Cited

UNITED STATES PATENTS

3,347,315	10/1967	Lanmon	166—42 X
2,718,264	9/1955	Allen et al.	166—23
2,766,828	10/1956	Rachford	166—42.1 X
2,832,415	4/1958	Reistle	166—35 X
2,839,142	6/1958	Huber	166—35
2,876,843	3/1959	Huber	175—4.56
3,011,551	12/1961	Young et al.	166—35 X
3,066,736	12/1962	Venghiattis	166—42.1 X
3,170,517	2/1965	Graham et al.	166—42.1
3,195,631	7/1965	Smith	166—35
3,198,268	8/1965	Lindblom et al.	166—42.1 X
3,343,600	9/1967	Phansalkar et al.	166—33

CHARLES E. O'CONNELL, Primary Examiner

A. CALVERT, Assistant Examiner

U.S. Cl. X.R.

166—305