United States Patent [19]

Turner et al.

[11] **3,884,301**

[45] **May 20, 1975**

[54] **METHOD OF GRAVEL-PACKING A HIGH-PRESSURE WELL**

[75] Inventors: **Eric B. Turner**, Pointe-a-Pierre, Trinidad And Tobago; **John A. Schell**, Morgan City, La.

[73] Assignee: **Texaco Trinidad, Inc.**, Pointe-a-Pierre, Trinidad And Tobago

[22] Filed: **Nov. 23, 1973**

[21] Appl. No.: **418,791**

[52] **U.S. Cl.** **166/278**

[51] **Int. Cl.** **E21b 43/04**

[58] **Field of Search** 166/278, 51, 276, 311, 166/312

[56] **References Cited**

UNITED STATES PATENTS

2,205,422	6/1940	Layne	166/278
2,677,428	5/1954	Clark	166/278
2,978,024	4/1961	Davis	166/278
3,134,439	5/1964	Shields, Jr.	166/51
3,421,586	1/1969	Solum	166/51
3,602,307	8/1971	Price et al.	166/278
3,627,046	12/1971	Miller et al.	166/278
3,695,355	10/1972	Wood et al.	166/278

Primary Examiner—Stephen J. Novosad

Attorney, Agent, or Firm—Thomas H. Whaley; C. G. Ries; Henry C. Dearborn

[57] **ABSTRACT**

A method of gravel-packing an oil well. It applies to wells that have high formation pressure so that weighted drilling mud was required in order to contain the pressure during drilling. The method uses a slotted liner and washpipe combination attached to the end of a tubing string. It involves first circulating out the drilling mud while holding back pressure to contain the formation pressure, and then reversing the flow with clean fluid to apply the gravel pack while still holding the back-pressure against the formation.

7 Claims, 3 Drawing Figures

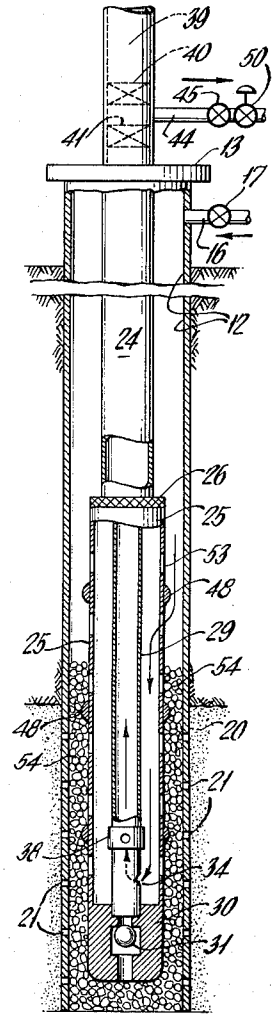


Fig. 1.

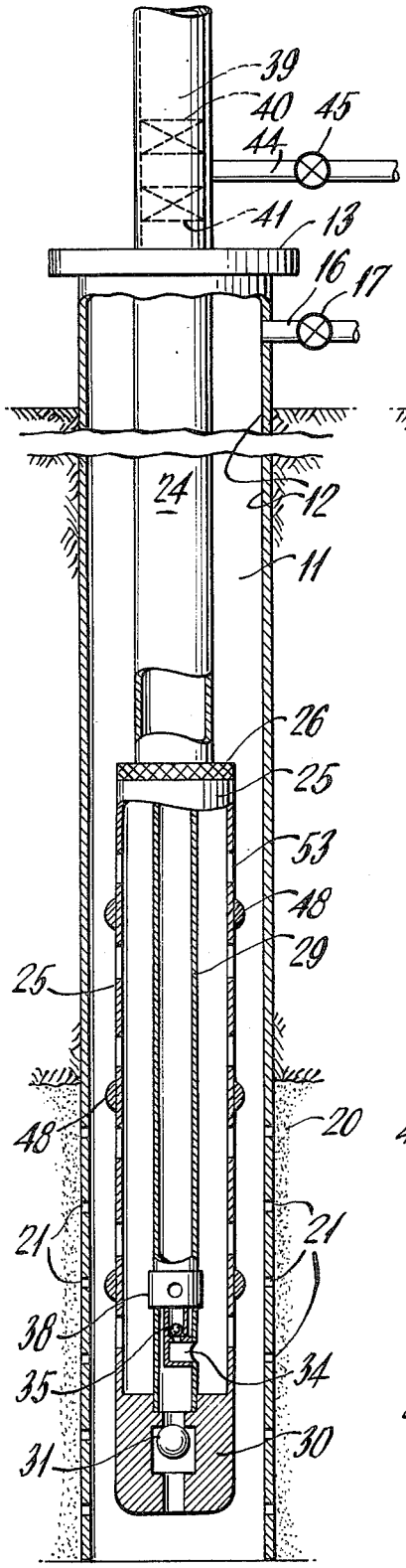


Fig. 2.

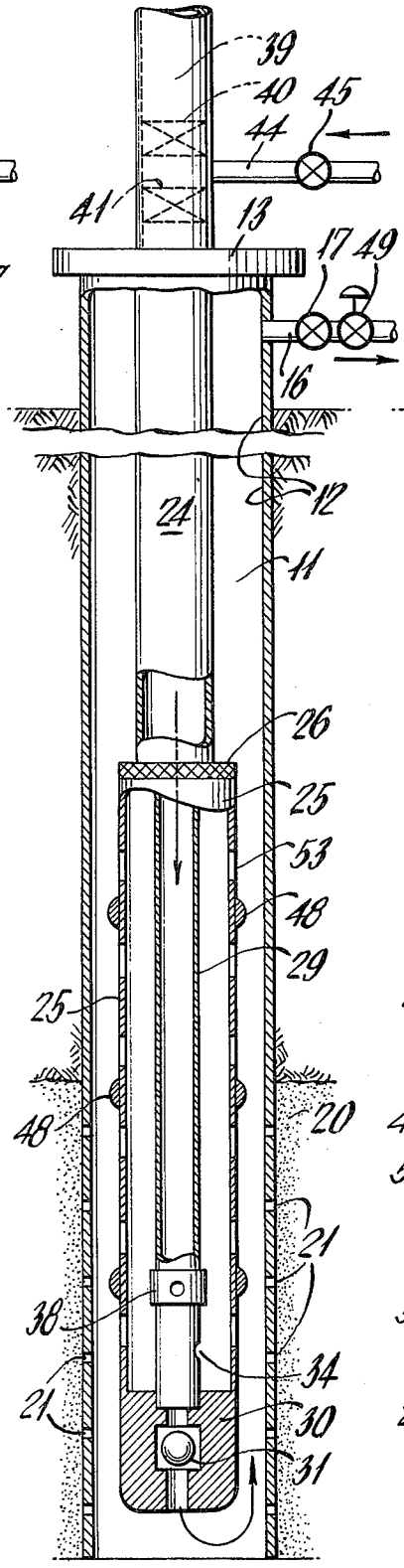
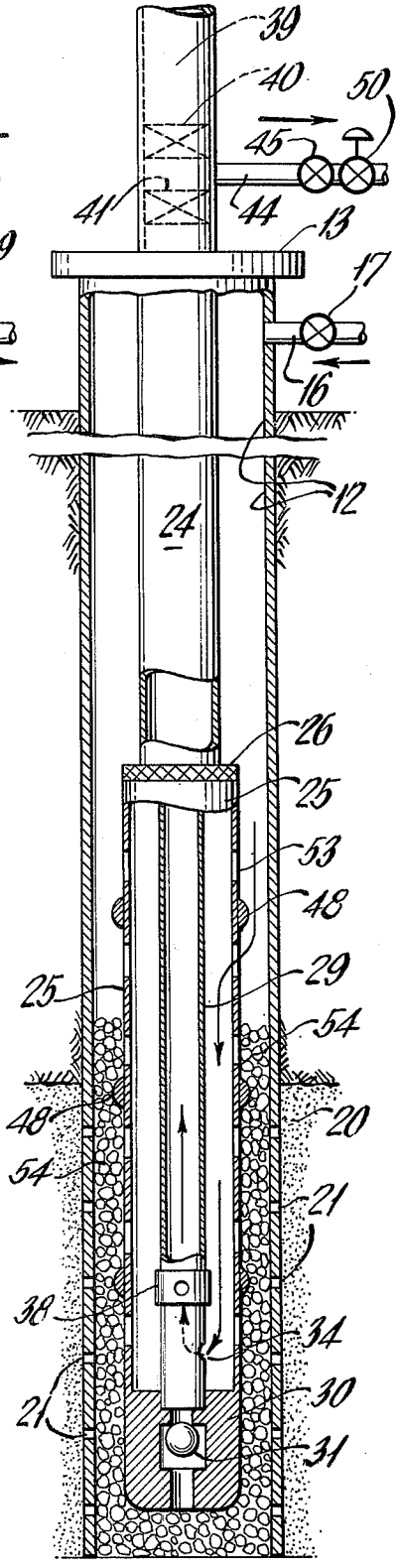


Fig. 3.



METHOD OF GRAVEL-PACKING A HIGH-PRESSURE WELL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention concerns oil-well drilling procedures in general, and more particularly relates to a method for gravel-packing of high-pressure wells.

2. Description of the Prior Art

While there have been various proposals and suggestions of different apparatus and/or procedures for carrying out gravel-packing of oil wells, such proposals and procedures have had different drawbacks. Furthermore, none of the known arrangements or methods have overcome the difficulties involved where a high-pressure formation is to be gravel-packed prior to being produced. It is especially difficult to remove all of the drilling mud from whatever packing material is employed.

Consequently, it is an object of this invention to teach a method of gravel-packing a high-pressure formation in the complete absence of any drilling mud on the gravel and while maintaining control of the high pressure.

Another object of the invention is to provide a method of gravel-packing that eliminates any pumping of drilling mud through the openings of a slotted liner, or screen, so that there is no risk of washing out a slot.

SUMMARY OF THE INVENTION

Briefly, this invention concerns a method of gravel-packing a well that penetrates a high-pressure formation wherein said well has a tubing string suspended within a casing. The method comprises the steps of positioning a screen and washpipe with valve means for permitting only downward flow from said tubing through said washpipe, and for controlling reversed flow upward into said tubing only near the lower end of said washpipe inside said screen, adjacent to said formation. It also comprises the steps of displacing mud from said well adjacent to said formation while holding sufficient pressure to contain said high-pressure formation, by circulating a wash fluid down said tubing string. And it comprises the step of placing gravel to pack said well opposite said formation by reversing said wash fluid circulation to flow said gravel down the well annulus while continuing to hold said containment pressure, whereby an uncontaminated gravel pack of a high-pressure formation is obtained.

Again, briefly, the invention concerns a method of producing a well having formation pressure higher than that which can be controlled by unweighted fluid, said well having been completed with a casing head and casing valve connection. The method comprises the steps of making up an assembly of a slotted liner and washpipe therethrough, with a washdown shoe at the bottom having a back-pressure check valve therein. The said assembly also has a washpipe port and valve means near the lower end of said washpipe, inside of said liner. The method also comprises running said assembly into said well at the bottom of a tubing string, on a releasing device, until said assembly is opposite the producing formation. And it comprises flanging said tubing up to said casing head. It also comprises installing a christmas tree for controlling fluid flow in said tubing, and displacing the drilling mud by pumping clear fluid down through said tubing while holding back-pressure at said casing valve connection to maintain control at said formation. In addition, it comprises reversing said clear fluid flow while holding back-pressure at said christmas tree and flowing gravel down said casing to place a gravel pack outside of said liner while said clear fluid returns through said washpipe valve means and up said tubing. And it comprises squeezing said gravel pack by closing said christmas tree valve and increasing the pressure on said clear fluid. The method also comprises removing said squeeze pressure and producing said well through said gravel pack with said casing valve closed. And it comprises disengaging said assembly and continuing to produce through said tubing after the formation pressure has declined to a safe level.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects and benefits of the invention will be more fully set forth below in connection with the best mode contemplated by the inventors of carrying out the invention, and in connection with which there are illustrations provided in the drawings, wherein:

FIG. 1 is a schematic view, largely in cross-section, illustrating a well with equipment to be used in carrying out the invention;

FIG. 2 is a similar schematic illustration as FIG. 1, but with arrows added to indicate the flow paths during a portion of the method according to the invention; and

FIG. 3 is another schematic illustration similar to FIGS. 1 and 2, illustrating different flow paths as well as showing the introduction of gravel to the well, according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As indicated above, there have been various proposals for applying gravel-packing in order to produce a well therethrough. However, the procedures have involved difficulties or have been unsatisfactory for various reasons, among which has been the problem of residual drilling mud which tends to make the gravel pack less effective. In particular, the prior procedures have not considered the situation where a high-pressure formation is to be produced and needs a gravel pack. A major problem in this situation relates to the fact that the high pressure of the formation must have been contained during drilling, by using weighted fluids as the drilling mud. However, by employing a special combination of elements along with a novel procedure, the well may be gravel-packed with a complete absence of any drilling mud.

Referring to FIG. 1, it should be noted that all of the various elements of this apparatus are, of course, only schematically indicated. Furthermore, they are all conventional oil-field equipment.

Also, it may be noted that while special reference is made to the use of a slotted liner, this piece of equipment may be generally described as a "screen." Thus, the function of the liner is like that of any type of screen, in that it has slots or other perforations of such size as to permit fluid flow while excluding the flow of solid materials such as the type generally used in gravel-packing.

In all of the three FIGURES of the drawings, the same elements are given identical reference numbers.

In FIG. 1, there is shown an assembly of most of the apparatus involved in the method according to this in-

vention. There is a well **11** that has been completed with a casing **12** and a casing head **13** at the surface. There is a flow pipe **16** that connects with the interior of the casing **12** below the casing head **13.** There is also a casing valve **17** in the pipe **16** for use in controlling the flow of casing fluids while carrying out the invention, as will appear more fully below.

It will be understood that this invention applies to a well whether or not it is cased all of the way down. However, the illustrations show the casing **12** extending down through a producing formation **20.** At this location in the well, there are perforations **21** through the casing. Of course, such perforations have been made to permit flow of the oil or other products when the well is produced.

Apparatus employed in connection with this invention includes a tubing string **24** that is supported at the casing head **13.** String **24** is made up with a slotted liner **25** attached to the lower end of the tubing by means of a releasing device **26.** There is a washpipe **29** that is located coaxially inside the slotted liner **25.** The washpipe is connected for fluid flow directly with the tubing string **24,** and the upper end of the slotted liner **25** is not connected with the interior of the tubing **24.**

At the bottom of the slotted liner or screen **25,** there is a washdown shoe **30** that has check valve **31** therein to permit flow from the interior of the tubing string **24** and the washpipe **29** only to go into the annulus of the well **11** that surrounds the tubing string **24.**

In addition, there is at least one of two flow connections through the walls of the washpipe **29** near the lower end thereof, but inside of the slotted liner **25,** i.e., near the shoe **30.** One of these connections is that indicated by a port **34** which has a reverse check valve **35** (FIG. **1**) associated therewith so that only fluid flow from within the liner **25** toward the interior of the washpipe **29** is permitted. The other flow connection is a slide-door sliding sleeve valve **38.** It may be operated by wire line or by hydraulic action, as desired, to control the flow of fluid from the inside of the slotted liner **25** to the interior of washpipe **29,** near the lower end thereof.

As indicated, either one or the other of the foregoing two flow connections is required for carrying out the invention. As the procedure is explained in more detail below, it will be clear that both may be used if desired.

At the top of the well, there is also a christmas tree **39** that includes at least two conventional valves **40** and **41,** as schematically indicated, to control flow of fluid within the tubing string **24** and to a tubing connector pipe **44** that has a valve therein.

In addition to the elements of apparatus that are described above, there are items such as a plurality of centralizers **48** located on the slotted liner **25.** It will be understood that these are preferably of a type that may be removed by drilling after the equipment has been placed in the well. Also, in FIGS. **2** and **3,** there are shown chokes **49** and **50** which are located in the flow line connections from the casing and tubing, respectively. As will appear more fully hereafter, these chokes are employed in connection with maintaining back-pressure as required.

It will be understood by anyone skilled in the art that additional apparatus of a conventional nature may be employed in connection with the elements illustrated. For example, the slotted liner **25** may include telltale slots (not shown) located just above the top row of slots **53** at the bottom of the top blank portion of the liner **25.** These telltale slots help to determine when the gravel pack has covered all of the slots or perforations in the liner **25.** Also, of course, additional equipment includes necessary fluid pumps with piping connections, e.g., of the type illustrated in the U.S. Pat. No. 2,213,962 to L. A. Layne, Sept. 10, 1940, which is assigned to the assignee of this application.

The method according to this invention may be best described with reference to FIGS. **2** and **3.** It will be understood that the well **11** has been drilled and found to penetrate a producing zone of formation **20** that has a high pressure such that weighted drilling mud was required to contain such pressure and keep from having a blow-out. Consequently, the presence of the drilling mud presents a contaminant for any gravel-packing that is to be applied prior to producing the well.

A first step, according to this invention, provides for circulating a clean fluid such as water or clean oil down the tubing **24.** As indicated by the arrows in FIG. **2,** this circulating fluid will flow down through the washpipe **29** and out the bottom of the shoe **30** to displace the drilling mud in the well **11.** This circulation continues as the fluids flow up inside the casing **12** in the annulus of the hole **11** and out through the pipe **16** and valve **17.** It also must pass through the choke **49.**

As the drilling mud is displaced, hydrostatic pressure on the formation **20** would be reduced, but back-pressure is maintained by manipulating the choke **49.** This is done in such a manner that the formation pressure is always contained.

The washing operation is continued until all of the drilling mud is cleared out from the formation **20** and perforations **21.** Then, as indicated by the arrows in FIG. **3,** the flow of clear fluid is reversed while gravel **54** is introduced with this circulating fluid into the flow pipe **16.** It travels in this opposite direction with the clean fluid acting as carrier. The return flow of this carrier fluid goes through the slots **53** of the liner **25** as the gravel **54** settles around the outside. Of course, the gravel **54** cannot pass through the slots **53.**

The reversed fluid flow continues from inside the slotted liner **25** through the port **34** and check valve **35** to the interior of the washpipe **29,** and then up through the tubing string **24** to the connector pipe **44.** Of course, if it is included, this reversed flow also goes through the sleeve valve **38,** which would have been opened, and then continues up inside the washpipe **29** to tubing **24** as before. The flow then goes out through the connector **44** and via the valve **45** to and through the choke **50.** Consequently, by manipulating the choke, the back-pressure is continued at a sufficient level to contain the formation pressure of the formation **20.**

If desired, and after the gravel-packing has been completely circulated into position, it may be squeezed into the formation by closing the valve **45** and raising the circulation pressure of the fluid entering pipe **16.** Thereafter, such squeeze pressure is released, and the well placed on production by closing the casing valve **17** and adjusting the connections from the christmas tree **39** to permit desired flow of produced oil from the well.

It will be noted that the produced oil flowing from formation **20** will pass through the perforations **21** and then through the gravel pack around slotted liner **25** (which now extends above the top of all the slots **53**),

so that produced formation sand may be removed by the packing in a conventional manner before the produced oil flows through the slots **53**. It, of course, continues from the interior of the liner **25** through the ports, now open, including sleeve valve **38** as well as port **34** and check valve **35**, into the washpipe **29** and up through the tubing **24** to the surface.

It should also be noted that the well is produced under the foregoing conditions, i.e., leaving the assembly of screen and attached elements in the well, until the formation pressure has declined to a safe level. Thereafter, if desired, the production flow may be assisted by artificial means such as gas lifting or pumping in which event the tubing would be withdrawn after disconnecting the releasing device **26** and re run with the appropriate equipment conventionally used for gas lifting or pumping but without the wash pipe **29**.

While the one embodiment of the invention has been described above in considerable detail and in accordance with the applicable statutes, this is not to be taken as in any way limiting the invention, but merely as being descriptive thereof.

We claim:

1. Method of gravel-packing a well that penetrates a high-pressure formation, wherein said well contains weighted drilling mud to control said high pressure, and wherein said well has a tubing string suspended within a casing, which comprises:

positioning a screen and washpipe with valve means for permitting only downward flow from said tubing through said washpipe and for controlling reverse flow upward into said tubing only near the lower end of said washpipe inside said screen adjacent to said formation,

displacing said mud from said well adjacent to said formation while holding enough pressure to contain said high-pressure formation by circulating a wash fluid down said tubing string, and

placing gravel to pack said well opposite said formation by reversing said wash fluid circulation to flow said gravel down the well annulus while continuing to hold said containment pressure,

whereby an uncontaminated gravel pack of a high-pressure formation is obtained.

2. Method according to claim **1**, which also comprises:

squeezing said gravel into said formation by stopping said reverse circulation at the top of said tubing string after said gravel is in place and applying a predetermined squeeze pressure.

3. Method according to claim **2**, which also comprises:

producing said well through said tubing string after said gravel-packing has been squeezed into the formation.

4. Method according to claim **3**, which also comprises:

disengaging said washpipe from said screen to continue producing the well after the formation pressure has declined.

5. Method according to claim **1**, which also comprises:

producing said well through said tubing string after said gravel-packing is completed.

6. Method according to claim **5**, which also comprises:

disengaging said washpipe from said screen to continue producing the well after the formation pressure has declined.

7. Method of producing a well having formation pressure higher than that which can be controlled with unweighted fluid, said well having been completed with a casing head and a casing valve connection, comprising:

making up an assembly of a slotted liner and washpipe therethrough with a washdown shoe at the bottom having a back-pressure check valve therein,

said assembly also having a washpipe port and valve means near the lower end of said washpipe inside of said liner,

running said assembly into said well at the bottom of a device until said assembly is opposite the producing formation,

flanging said tubing up to said casing head,

installing a christmas tree for controlling fluid flow in said tubing,

displacing the drilling mud by pumping clear fluid down through said tubing while holding back-pressure at said casing valve connection to maintain control at said formation,

reversing said clear fluid flow while holding back-pressure at said christmas tree and flowing gravel down said casing to place a gravel pack outside of said liner while said clear fluid returns through said washpipe valve means and up said tubing,

squeezing said gravel pack by closing said christmas tree valve and increasing the pressure on said clear fluid,

removing said squeeze pressure and producing said well through said gravel pack with said casing valve closed, and

disengaging washpipe and tubing from said assembly and continuing to produce through said tubing after the formation pressure has declined to a safe level.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,884,301

DATED : May 20, 1975

INVENTOR(S) : Eric B. Turner and John A. Schell

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 51 "claim 2" should read -- claim 1 --.

Column 6, line 3 "claim 3" should read -- claim 2 --.

line 8 "claim 1" should read -- claim 3 --.

line 12 "claim 5" should read -- claim 4 --.

Signed and Sealed this

second Day of *September 1975*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks