May 30, 1939. P. S. PUSTMUELLER 2,160,228

PROCESS AND APPARATUS FOR CEMENTING OIL WELLS

Original Filed April 11, 1938 2 Sheets-Sheet 1

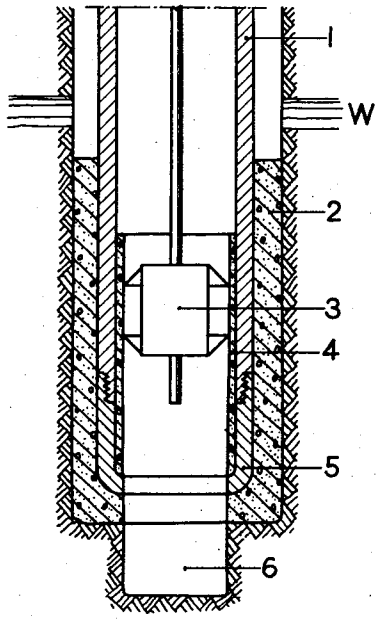


Fig. 1

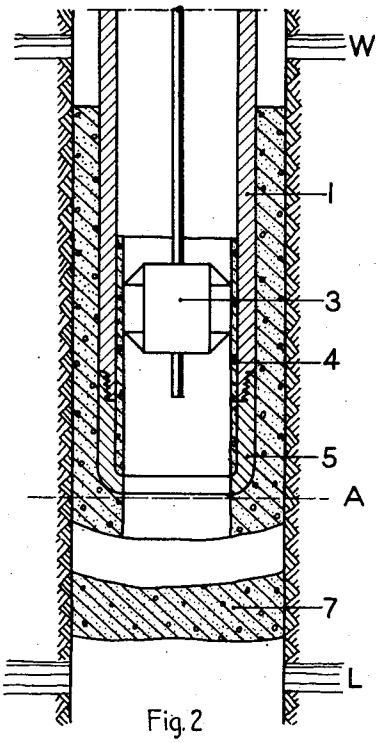


Fig. 2

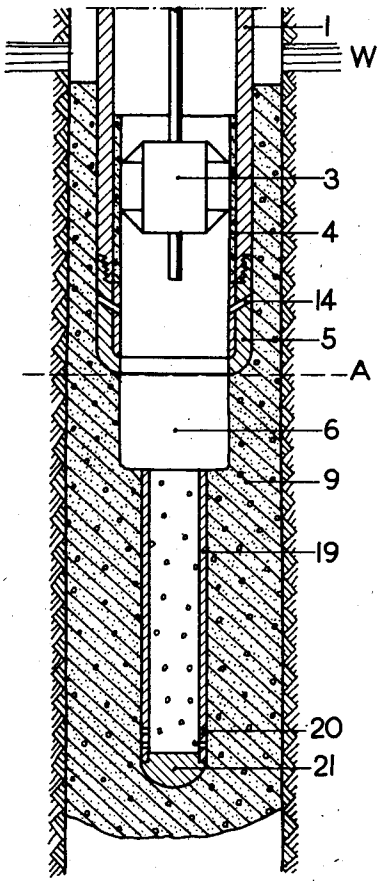


Fig. 3

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PROCESS AND APPARATUS FOR CEMENTING OIL WELLS

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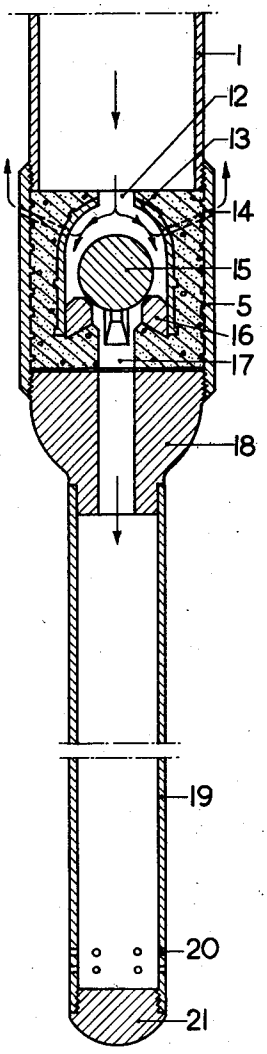


Fig. 4

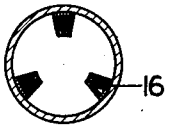


Fig. 5

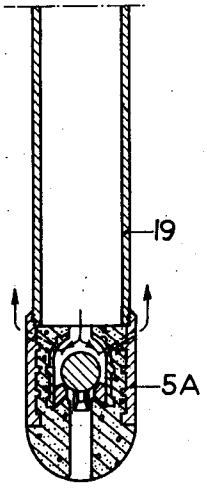


Fig. 6

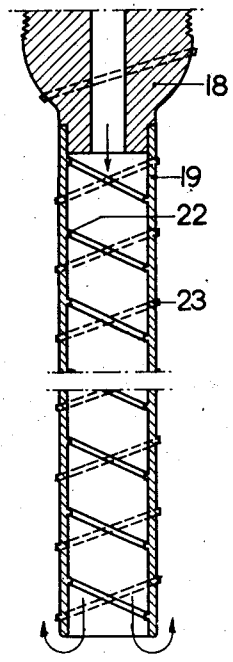


Fig. 7

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UNITED STATES PATENT OFFICE

2,160,228

PROCESS AND APPARATUS FOR CEMENTING OIL WELLS

Paul S. Pustmueller, Bakersfield, Calif., assignor to Shell Development Company, San Francisco, Calif., a corporation of Delaware

Original application April 11, 1938, Serial No. 201,346. Divided and this application December 19, 1938, Serial No. 246,617

10 Claims. (Cl. 166—1)

The present invention pertains to the art of cementing oil and gas wells, and is more particularly related to a process whereby the shoe or lower end of a casing string may be cemented at an intermediate level of the well, that is, at a point relatively distant from the bottom of the hole, and a bridging cement plug, necessary for testing the efficiency of water shut-off obtained by cementing the casing, may be placed below the casing shoe in a single operation without moving the casing.

The present application is a division of my copending application Serial No. 201,346, filed April 11, 1938.

The present invention will be understood from the following description, taken with reference to the attached drawings, wherein:

Fig. 1 diagrammatically illustrates a conventional application of the water shut-off test to a casing string cemented near the bottom of the borehole.

Fig. 2 diagrammatically illustrates a conventional application of the water shut-off test to a casing string cemented in an intermediate zone of the well.

Fig. 3 diagrammatically illustrates the application of the water shut-off test to a casing string cemented in an intermediate zone of the well according to the method of the present invention.

Fig. 4 is an elevation view in cross section of a preferred embodiment of the apparatus of the present invention.

Fig. 5 is a plan view of the open seat valve shown in Fig. 4.

Figs. 6 and 7 are elevation views in cross section of other preferred embodiments of the tail piece 19 shown in Fig. 4.

Present oil field practice requires that wells be properly cased and cemented off in order to prevent the dissipation of oil deposits into non-productive strata or to protect said deposits against contamination by aqueous liquids from adjacent formations. Some State laws prescribe that the effectiveness of cementing operations in shutting off fluid flow behind the casing be in each case tested according to definite regulations.

Whenever it is desired to cement a casing string extending substantially to the bottom of the borehole, the cementing operation and the water shut-off test do not present especial difficulties. In such cases as shown in Fig. 1 the casing shoe 5 is lowered at the end of a casing string 1 substantially to the bottom of the hole, a desired quantity of a cementing mixture is lowered into the casing, and pressure is applied to force said mixture through suitable passages in the shoe into the annular space 2 between the casing and the walls of the borehole, a certain amount of cement 4 remaining also in the lowest section of the casing. After the cement has set, a drill bit is lowered within the casing, and a hole 6 is drilled through the hardened cement remaining in the casing, through the casing shoe and through the formation below the plug, usually to a distance not exceeding five feet of said formation. A formation tester 3 such, for example, as the Halliburton or the Johnston formation tester, is then anchored in the hole drilled through the cement plug, and the efficiency of the water shut-off is determined by observing the fluid passing through said tester, an admixture to said fluid of a brine due to leakage through or around the cement plug from the water layer W indicating in such cases an imperfect cementing of the casing.

In some cases, however, it may be found desirable to cement the casing shoe at a point considerably above the bottom of the hole. This is done, for example, when the whole, or at least a portion of a producing sand has been penetrated, or the well has been drilled for coring or logging purposes to its total depth before the most advantageous point for cementing the shoe of the casing is determined.

In such cases, as shown in Fig. 2, if the casing shoe 5 is lowered to the desired level A, and cement is pumped down and out therethrough, the effect of the drilling fluid standing in the borehole and having approximately the same consistency and specific gravity as the cement will not permit the cement to settle for more than 1 or 2 feet below the shoe, the cement being therefore forced upwards around the casing. When, however, a hole is drilled through the casing shoe in order to apply a water shut-off test as before, it is obvious that such test will not be conclusive as to the efficiency of the cement plug placed in the annular space behind the casing, since it is not known whether any brine flowing through the formation tester 3 is due to leakage from the upper water layer W through or around the cement plug surrounding the casing, or to a flow of brine from a lower water layer L. In such cases, therefore, it is customary to place, as a preliminary operation, a bridging plug 7 at some point below the cementing level 6 to seal off the portion of the well extending below the casing shoe 5.

The placement of the bridging plug 7 is usually carried out by one of the following methods:

1. A desired quantity of cement may be "spotted" to the level 7 by means of bailers and left to set there, whereafter the casing shoe is lowered to the level A and cemented there in the usual manner.

2. A string of tubing is lowered to the level 7, and a desired quantity of cement is pumped down therethrough, whereafter the tubing string is withdrawn, the bridging plug 7 left to set, and the casing cemented at level A as before.

3. The casing string 1 is first lowered to level 7, a desired quantity of cement is pumped therethrough to form the bridging plug 7, whereafter the casing string is raised to level A, the bridging plug at 7 is left to set, and the casing is finally cemented at level 6, the water shut-off test being then carried out as before.

In using method 1 or 2, great difficulties are often experienced in placing an effective bridging plug due to admixture of the cement slurry with the drilling fluid in the borehole. Bridging operations must sometimes be repeated three or four times before a satisfactory bridging plug is placed, which entails a considerable loss of time and increases the cost of cementing operations. Moreover, even when the bridging operation has been successfully carried out, a loss of time is experienced since the bridging plug must be allowed to set before the main cementing operation, that is, the cementing of the casing shoe, may be performed.

The use of method 3 involves the additional danger of "freezing" the casing string at the level 7, that is, below the desired level A, due to a premature setting of the cement, and should not be attempted at any depth greater than 4000 feet.

All three of these methods have the additional drawback of badly damaging the drilling fluid system by contamination with cementing slurry during the bridging operation. Since it is especially important to have the drilling fluid in good condition at the time, when the casing string is being set to prevent "freezing" due to the effect of settling cuttings or sloughing formations, a cementing method which eliminates the necessity of a separate bridging operation becomes of considerable value.

Furthermore, the circulation of a cement-contaminated drilling fluid in contact with the face of oil-bearing sands often causes a partial plugging of the latter and results in wells of reduced productivity.

It is therefore the object of the present invention to provide a method and an apparatus for cementing a string of casing in an intermediate zone of the well and for placing a bridging cement plug below the casing shoe at the time and as a part of the regular casing cementing operation, whereby the time necessary for such operation is considerably reduced, and the danger of contaminating the drilling fluid during the bridging operation is eliminated.

Referring to Fig. 4, the apparatus of the present invention comprises a string of casing 1, supporting a casing shoe 5, made of or comprising a drillable material such as cast iron, aluminum, bronze, cement, or any combination of these or similar materials. The casing shoe comprises a valve, such as a ball valve 15, or a non-return valve of any other desired type. The ball valve 15 is held within a housing 13, having an axial passage 12 forming an upper seat adapted to close the valve against any upward fluid flow, and with a downward axial passage 17 provided with an open seat 16, shown in detail in Fig. 5, which permits a downward flow of fluid through the valve. The housing 13 is also provided with ports and passages 14, leading through the casing shoe upwards and at an angle designed to give the fluid passing therethrough a whirling motion on issuing out of the shoe. The cross-sectional area of the passages 14 is adjusted in such manner with regard to the cross-sectional area of the main downward passage 17, that the liquid passing through the valve is automatically proportioned into streams having any desired capacity ratio, for example, 40 percent thereof passing through the whirler ports 14, and 60 percent through the main downward passage 17.

A drillable swage 18 is attached to the lower portion of the shoe 5, and serves to support the tail piece or tubing section 19, which has preferably an outside diameter smaller than the inside diameter of the casing string, and is made of an easily drillable material such as aluminum, Bakelite, hard rubber, brass, cast iron, etc. The tail piece 19 is usually from 10 to 20 feet long, being closed at the bottom by a screw plug 21, made of the same material, and provided in its lower portion with perforations 20 to permit a fluid flow therethrough.

As shown in Fig. 6, a drillable float shoe 5A, provided with a valve similar in construction to that of the casing shoe 5, may be used if desired instead of the screw plug 21 at the lower end of the tail piece 19, or said lower end may be left open, as shown in Fig. 7. It may likewise be desirable to provide the tail piece 19 with inside or outside rifling, or both, as shown at 22 and 23 in Fig. 7. This rifling may be grooved on or attached to the tail piece in a manner well known to the art, and serves to give the cement slurry descending through the tail piece or ascending around it a whirling motion.

In placing a bridging plug and cementing a casing string in an intermediate well zone, that is, at a point considerably above the bottom of the borehole, the following procedure may be followed according to the present invention.

Referring to Fig. 3, the casing shoe 5, provided with the tail piece 19, is lowered into the borehole at the end of a casing string and placed at the exact level A where it is to be cemented, the tail piece 19 extending to approximately from 10 to 20 feet below said level. A desired amount of cement, such, for example, as three to five hundred sacks, or more, is then made into a slurry of any desired water content, and is pumped down the casing, followed by a solid wooden or rubber plug to which fluid pressure is applied from the top. The cement slurry is thereby forced out of the casing, a certain proportion thereof issuing through the whirler ports 14 into the space around the casing shoe, and another portion issuing through the perforations 21 in the lower portion of the tail piece 19 into the space around said tail piece. The borehole being filled with a drilling fluid whose consistency and specific gravity do not greatly differ from that of the cement slurry, the latter has no tendency to settle down to a greater distance than 1 or 2 feet below the plug 21, and is forced upwards to a point considerably higher than the casing shoe 5, completely filling the annular space between the casing, casing shoe and tail piece, and the walls of the borehole. When the wooden or rubber plug following the cement charge within the casing string strikes the casing shoe 5, or a special stop for said plug provided within the casing string at some distance, such as one casing stand

above the casing shoe, the fluid flow is stopped, and a rise of pressure indicates to the operator that the whole of the cement slurry has been forced into the borehole, excepting a small portion within the casing and tail piece below said wooden plug. The cement slurry is then allowed to set, a considerable saving of time being effected due to the fact that the bridging plug, that is, the cement within and around the tail piece 19, can be allowed to set at the same time with the cement used for the main cementing operation, that is, with the cement in the annular space around the casing string 1. In view of the fact that the bridging plug is placed within and around the tail piece 19, which serves as a metallic member reinforcing the cement, the cement slurry has no appreciable tendency to mix and be diluted or absorbed by the drilling fluid within the borehole and the formation of the bridging plug is thereby positively insured.

After the cement slurry has set, a drill bit is lowered within the casing string, and the hardened cement within the lowest casing joint, the friable casing shoe, as well as the upper portion of the tail piece 19, together with the cement in which it is embedded, is drilled out to a distance not exceeding about 5 feet below the casing shoe, that is, to a distance equal to approximately from one-fifth to one-half of the tail piece 19, as shown at 6 in Fig. 3. A formation tester 3 is then anchored within the hole thus drilled, and a water shut-off test is run in the usual manner

It will be noted that, although the space 6 is not actually in contact with the formation through which the well has been drilled, the annular body of cement 9 separating said space from the walls of the borehole has a relatively small thickness, such as about 2 inches, and is, moreover, considerably cracked and damaged during the drilling of the space 6, being therefore quite pervious to fluid flow. Suitable and well known means may furthermore be used to break and/or remove said annular body of cement. If, therefore, the cement plug around the casing string, or the bridging plug around the tail piece 19, have been imperfectly placed, and leakage through or around said plug takes place from any upper water layer, the leaking fluid will easily penetrate into space 6, and can be detected by means of the formation tester.

I claim as my invention:

1. In a process for cementing a well casing, the steps of attaching thereto a shoe supporting a drillable tubing section of substantial length, said shoe having transverse passages communicating with the outside of the casing and a downward passage coaxial with said tubing section, lowering said shoe to the desired level within the borehole, lowering a cement slurry into said casing and tubing, applying downward pressure thereto within the casing, forcing said slurry out of the casing shoe passages and out of the lower end of the tubing, and causing said slurry to fill the annular space between said casing and tubing and the walls of the borehole to a point above the casing shoe.

2. In a process for cementing a casing string at an intermediate level of a borehole filled with a drilling fluid, the steps of attaching to said casing a drillable shoe supporting a drillable tubing section of a smaller diameter than said casing, said shoe having transverse fluid passages communicating with the outside of the casing, and a downward passage coaxial with the tubing section, lowering said shoe to the desired level within the borehole, lowering a cement slurry into said casing and tubing, applying downward pressure thereto within the casing, forcing a portion of said slurry out of the casing through the transverse passages of the shoe, forcing another portion of said slurry out of the lower end of the tubing, causing said slurry to fill the annular space between said tubing and casing and the walls of the borehole to a point above the casing shoe, discontinuing the pressure when substantially all the slurry has been driven out of the casing, allowing the tubing to remain filled with the slurry, allowing the slurry within the borehole to set, lowering a drill bit within the casing, drilling out the casing shoe, and not more than five feet of the upper portion of the tubing, and testing the space thus drilled out for the leakage of fluids through the cement plugs formed above the casing shoe.

3. In an apparatus for simultaneously cementing a casing in a borehole filled with a drilling fluid and placing a bridging plug below the shoe of said casing, a casing strip, a shoe attached to the end of said casing, transverse passages through said shoe in communication with the outside of the casing, an axial passage through said shoe, and a drillable tubing section supported by the shoe and coaxial with said last passage, said tubing section having an outside diameter smaller than the inside diameter of the casing.

4. In the apparatus of claim 3, a spiral rifling on the outside wall of the tubing section.

5. In the apparatus of claim 3, a spiral rifling on the inside wall of the tubing section.

6. In the apparatus of claim 3, a spiral rifling on the inside and outside walls of the tubing section.

7. In an apparatus for simultaneously cementing a casing in a borehole filled with a drilling fluid and placing a bridging plug below the shoe of said casing, a casing string, a drillable shoe attached to the end of said casing, transverse passages through said shoe in communication with the outside of the casing, an axial passage through said shoe, a drillable tubing section supported by the shoe and coaxial with said last passage, said tubing section having an outside diameter smaller than the inside diameter of the casing, a plug closing the lower end of said tubing section, and a plurality of perforations in the lower portion of said tubing section above said plug.

8. In an apparatus for simultaneously cementing a casing in a borehole filled with a drilling fluid and placing a bridging plug below the shoe of said casing, a casing string, a drillable shoe attached to said casing, a vertical passage through said shoe, a non-return valve allowing a downward fluid flow within said passage, means comprising a plurality of fluid passages in communication between said valve and the outside of the shoe for causing a predetermined proportion of the fluid passing downwardly through the valve to issue through said passages transversely of the shoe, and a drillable tubing section supported by the shoe and coaxial with the vertical passage through the shoe, said tubing section having an outside diameter smaller than the inside diameter of the casing.

9. In the apparatus of claim 8, a drillable shoe attached to the end of said tubing section, a vertical passage through said shoe, a non-return valve allowing a downward flow through said pas-

sage, and a plurality of transverse fluid passages in communication between said valve and the outside of said shoe.

10. In an apparatus for simultaneously cementing a well casing in a borehole filled with a drilling fluid and placing a bridging plug below the shoe of said casing, a casing, a shoe attached to the end of said casing, transverse passages through said shoe in communication with the outside of the casing, an axial passage through said shoe, and a drillable tubing section supported by the shoe and coaxial with said last passage, the lower outlet of said tubing section being at a substantial distance below the casing.

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