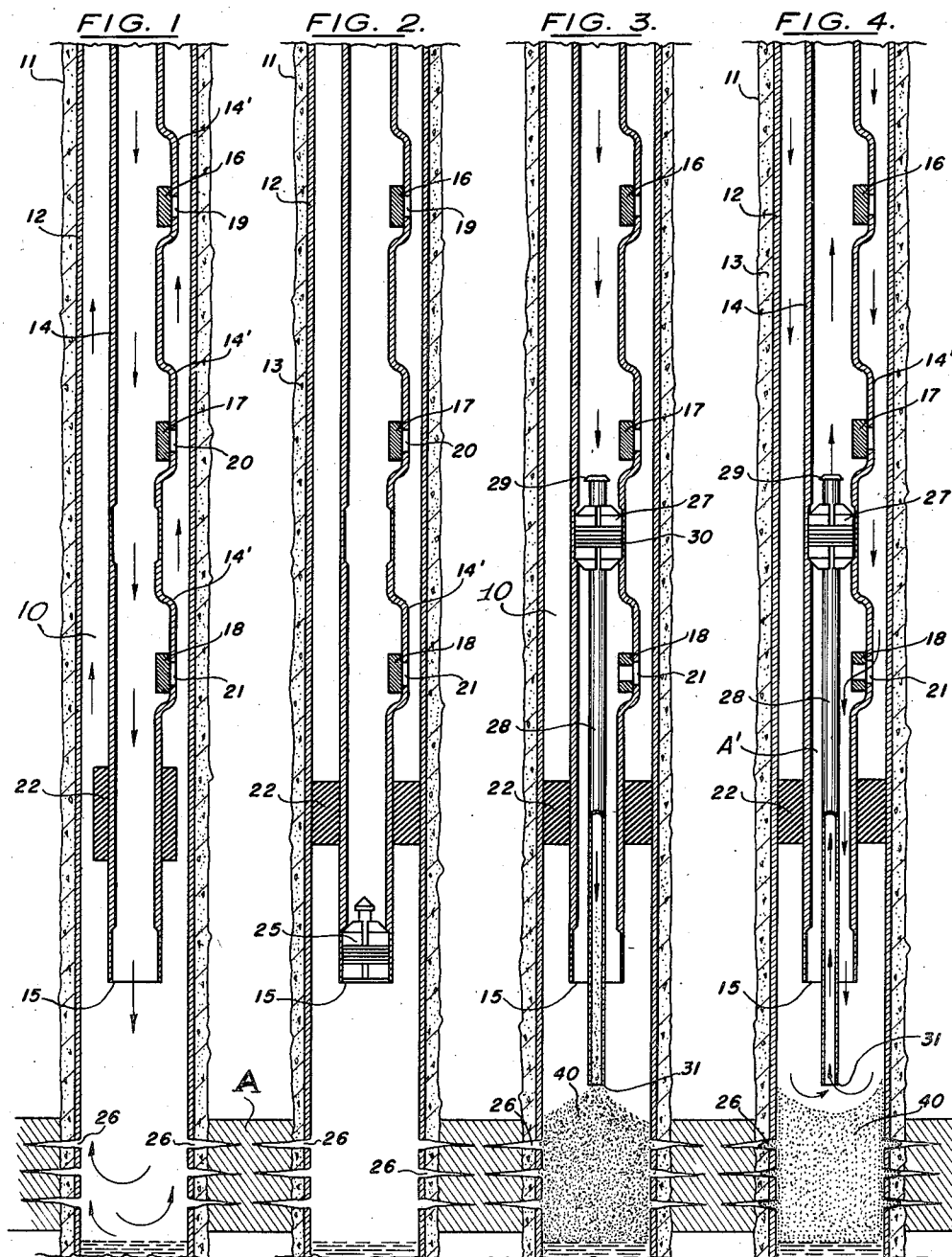


Dec. 4, 1956

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METHOD FOR COMPLETION OF WELLS HAVING
HIGH BOTTOM HOLE PRESSURES
Filed Oct. 19, 1953

2,772,738



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METHOD FOR COMPLETION OF WELLS HAVING HIGH BOTTOM HOLE PRESSURES

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Application October 19, 1953, Serial No. 386,767

8 Claims. (Cl. 166—22)

The present invention is directed to a method for completing a well under abnormal bottom hole pressure. More particularly, the invention is directed to cementing a well having an abnormal bottom hole pressure without contaminating a particular stratum with mud. In its more specific aspects, the invention is directed to a method for cementing a high bottom hole pressure well without killing the well with mud.

The present invention may be briefly described as a method for completing or working over a well having a high bottom hole pressure in which a perforated casing in a stratum pierced by said well is to be cemented. The well is provided with a tubing arranged in the casing with the lower end of the tubing above the particular stratum in which the casing is perforated. A column of clean fluid is established in the well and pressure is provided on said column in excess of the bottom hole pressure of the well. The column is extended to a point in the well adjacent the perforations. Cement and/or other fluid material is introduced into the well down the column to the point adjacent the perforations and a cement or fluid is then forced into the perforations and/or the stratum. In the case of cement, the perforations are sealed by allowing cement to set while maintaining a pressure in excess of the bottom hole pressure on the well.

The present invention may be employed to introduce any fluid material, such as cement and the like, into a well having an abnormal bottom hole pressure. For example, a cement slurry, an acid, an acid gel, and many other fluid or liquid materials may be introduced into the well either to treat the well or treat the formation or to seal the perforations in the casing.

The invention will be further illustrated by reference to the drawing in which:

Fig. 1 illustrates a well penetrating a strata at the initial stage of the operation;

Fig. 2 shows the well in an intermediate stage;

Fig. 3 shows the introduction of fluid materials in the well; and

Fig. 4 illustrates the removal of excess fluid material from the well.

Referring now to the drawing, numeral 11 designates a well in which a casing 12 has been run and cemented in place with cement 13. A tubing 14 has been arranged in the well with its lower end 15 located at a point above a formation or stratum A which is to be treated or sealed as the case may be. The stratum A may be the first of a series or plurality of productive intervals or strata separated by non-productive stratum or the stratum A may be the upper zone of a particular productive interval and it is desired to seal the upper zone.

The tubing 14 may be provided with a plurality of mandrels 14' in which are arranged retrievable valves 16,

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17 and 18 which serve to close ports 19, 20, and 21 in the mandrels 15.

The annulus 10 between the tubing 14 and the casing 12 is closed by a packer 22.

In Fig. 2, the apparatus of Fig. 1 is shown with a wire line retrievable plug 25 arranged above end 15 of the tubing 14. This plug 25 may be suitably constructed of magnesium and the like material and may be provided with slips and packing and constructed to hold pressure from the downward direction. A plug of this nature is marketed by Otis Pressure Control, Inc., and described on page 3979 of the Composite Catalog, 1953 edition.

It is to be noted that the casing 11 has been perforated in the stratum A and perforations 26 have been opened up between the casing and the stratum A.

In Fig. 3, there is shown arranged in the tubing 14 on a landing nipple 27 in the lower section thereof a tubular extension member 28 which is provided with a fishing neck 29 which allows the tubular extension member 27 to be raised and lowered in the tubing 14. The space between the tubing 14 and the tubular extension member 28 is packed or sealed off by means of packing or sealing means, such as chevron packing 30. The tubular extension member 28 is shown with its lower end 31 a substantial distance below the lower end 15 of the tubing 14 and adjacent or in the vicinity of the perforations 26.

The showing of Fig. 4 is similar to that of Fig. 3 with the exception that the valve 18 is shown in an open position allowing communication between the annulus 10 and the tubing 14.

The present invention may operate in a number of ways. For example, the invention may be operated using a clean liquid throughout the operation or using a clean liquid and mud such that only the clean liquid contacts the formation. In short, the preferred and required mode of the present invention is that clean liquid only contacts the stratum A which is to be sealed with cement.

Referring again to Figs. 1 and 2, the casing 12 and the tubing 14 are allowed to load up with water, gas, or oil which may suitably be salt water and oil from the well. In any event, the well including the casing 12 and the tubing 14 are allowed to become completely filled or is filled with the clean fluid. It will be noted that the packer 22 has been set and that the annulus 10 is isolated from the lower portion of the well.

Thereafter with respect to Fig. 2 the plug 25 is lowered on a wire line and set at a point immediately above the open end 15 of the tubing 14. Fluid communication is then established between the tubing and the casing at a point immediately above the packer 22 by opening up the valve 18 by suitable equipment well known to the art and as described in the Composite Catalog, supra, at page 1059 of the 1953 Ed. The well head pressure is then released allowing the plug 25 to withstand the pressure differential, that is, the difference between the formation pressure and the hydrostatic pressure in the tubing 14. Circulation is then established down the casing, down the annulus 10 and through the port 21 and thence up the tubing 14 as indicated by the arrows. Suitably this circulation may be in the opposite direction, as desired. The purpose of this circulation with the clean fluid, such as water or oil, is to remove any entrained gas which may be trapped in the water or the oil. As shown in Fig. 3, the tubing extension member 28 is then lowered on a wire line from the earth's surface. Suitably the landing nipple 30 may be replaced by other supporting or securing means, such as slips, latching dogs, and the

like. It will be noted that the tubing extension 28 is run into the tubing 14 as if the well were dead in that the plug 25 has closed off the tubing from the well by the packer 22. Before the tubing extension is lowered and landed in the landing nipple 30, the well, which is closed in by packing off around the wire line suspending the member 28, is pressured up with clean fluid at the surface to create a pressure differential in excess of the formation pressure. This causes the plug 25 to blow out the end of the tubing 15 allowing the tubing extension member 28 to drop into position in the landing nipple 30 as shown in Fig. 3. Thereafter the clean fluid, such as oil or water, is extended down to the perforations 26 and cement is introduced into the tubing 14 down through the extension member 28 and out the end 31 thereof and into the casing 26 adjacent the stratum A to deposit a body of cement 40 in the casing. After the cement 40 has been deposited in the casing, pressure is imposed on the column of fluid in the tubing 14 and the extension member 28 and the lower portion of the casing 12 by the hydrostatic head or by imposition of pressure from the surface. This causes the cement to be squeezed through the perforations 26 and to deposit in the stratum A, if desired, and seal the perforations 26. It will be noted that all during these operations the port 21 has been opened by the valve 18. It is possible to operate, however, with the valve 18 closed to circulation from the tubing only thereby preventing pressure from below the packer being exerted on the casing above the packer.

After the cement has been deposited and squeezed into the stratum A, the valve 18 is opened to allow communication through the port 21 from the annulus 10 into the interior of the tubing 14 and to allow circulation down the annulus 10 through the port 21 into the annulus A', down the annulus A' into the casing 12 below the packer 22, then upwardly through the extension member 28 and the tubing 14 to the earth's surface, causing excess fluid cement in the well to be removed down to a point below the open end 31 of the extension member 28. The pressure differential is maintained on the well until the cement is set. After these operations, the well may be reperforated by removing the extension member 28 on a wire line and running a tubing gun perforator down the tubing 14 to perforate the well at a point above the perforations 26 as may be desired. It may be desirable and preferable under some circumstances, however, to pull the extension 28 up into the tubing 14 or remove it completely from the tubing 14 after excess fluid cement has been circulated out. Otherwise, under some conditions, such as with a small amount of cement remaining in the casing 12, the extension member 28 might become stuck or cemented therein.

The invention is also susceptible to use while employing mud. For example, in the setup as illustrated in Fig. 1, with the tubing located immediately above the stratum A, the tubing is allowed to load with clean fluid or fluid is placed in the tubing 14 by some means. The valve 18 may be opened up or removed, and mud in the annulus 10 is displaced with salt water by direct circulation until the combined hydrostatic head of the salt water and mud in the casing 12 is exceeded by the formation pressure by some small value of several hundred pounds per square inch. Mud is then pumped into the tubing 14 until the mud columns in the tubing 14 and the casing 12 are substantially equal, leaving the tubing and casing hydrostatic heads about 100 to 1000 pounds per square inch pressure less than the bottom hole pressure. It is necessary in this particular operation to provide sufficient water in the column in the casing to exceed the volume of the mud in the column in the tubing.

As illustrated in Fig. 2, a blowout plug 25 of the type described is planted or located in the lower end of the tubing. Pressure is then bled from the tubing 14 and casing 12 at the surface leaving both the tubing 14 and the casing 12 above the packer 22 with 0 pound per square

inch surface pressure. The valve 18 is open and the tubing extension 28 is lowered into the well and locked in the landing nipple 30, as shown in Fig. 3. Prior to locking the tubing extension member 28 in the landing nipple 30, the plug 25 may be removed by pressuring up the tubing 14 until the pressure differential at the plug 25 is sufficient to force the plug 25 from the tubing 14; the plug 25 may also be tapped in a downward direction by the end 31 of the tubing extension 28, if necessary. Mud is then pumped into the casing 12 until the mud in the tubing 14 is displaced with salt water, valve 18 remaining opened to allow the mud in the tubing to be displaced upwardly, leaving salt water in the tubing and mud and salt water or mud, alone, in the casing. If desired, formation pressure may be used as an aid in removing mud from the tubing 14. During these operations there may be little or no pressure in the casing 12 above the packer 22 and the pressure on the tubing at the surface is equal to the difference between the hydrostatic head of salt water and the formation pressure. Valve 18 may then be closed and, thereafter, fluid cement slurry is pumped into tubing 14 under pressure, as shown in Fig. 3, forcing salt water into the formation. If valve 18 is allowed to remain open, however, the salt water may be displaced upwardly in the casing and then through port 21 into the tubing 14. The cement in the tubing 14 is followed with mud or other suitable fluid such as water and the like until satisfactory pressure differential exists into the formation, indicating a satisfactory squeeze cementing operation.

As shown in Fig. 4, mud or salt water is then pumped into the casing to reverse the excess cement from the tubing, the valve 18 being opened and communication being had from the annulus 10 to the annulus A' and thence up the extension 28 and tubing 14. If the amount of excess fluid cement in the casing 12 is large and the weight of the cement is less than that of the mud or if the water cushion between the mud and the cement while reversing is excessive, care must be taken to reverse this fluid through a choke to maintain a pressure differential into the formation. After the operation is complete, the well is left with mud in the casing or tubing or both of sufficient weight to overbalance the bottom hole pressure. The tubing 14 and casing 12 may be left with water in them and pressure may be placed on these columns at the surface if desired. The tubing extension 28 may then be retrieved or left in place, as desired.

After the cement has set, the extension 28 may be rerun on a wire line, not shown, and the mud may be displaced with water. Mud may be left in the annulus 10 and the well may be reperforated with a tubing gun perforator, if desired. When the mud is displaced with salt water or other fluid a pressure differential in the well bore will exist.

It is to be understood that the foregoing described operation may be used to treat a stratum or formation with fluid without the stratum or formation becoming contaminated with mud.

It is to be understood that the foregoing technique may depend on the maximum pressure that may be handled on the tubing which is created by the difference of hydrostatic head in salt water, for example, and the formation pressure. If the maximum pressure differential between the hydrostatic head of salt water and formation pressure is less than the permissible casing pressure, the mud or salt water in the annulus 10 may be circulated from the well and mud may be placed in the tubing until the head equals or exceeds the formation pressure and then a casing valve at the surface is closed at this point. The tubing extension 28 may be run and the mud may then be circulated from the tubing 14, as desired, by reverse circulation from the annulus 10 to the annulus A' while placing mud or other fluid in the casing prior to the cementing operation. In this sort of operation, the use of the plug 25 is not required. Wells

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with abnormal bottom hole pressure, such as one having a pressure gradient greater than 0.465 pound per square inch per foot of depth may also be handled successfully without drilling mud touching the formation or strata A, the part 21 in the lower of the mandrels 14' remaining open and sufficient salt water is then pumped into the tubing to displace mud out of the casing 12 until a low pressure is indicated on the casing 12 at the surface. At this point the tubing extension member 28 may be run into the tubing 14 under pressure. The subsequent steps in such operations would be similar to those described before.

The nature and objects of the present invention having been completely described and illustrated, what I wish to claim as new and useful and to secure by Letters Patent is:

1. A method for cementing a high bottom hole pressure well provided with a perforated casing in a stratum pierced by said well and having a tubing arranged therein with its lower end located above said stratum without contaminating said stratum with mud which comprises forming a first column of mud and a second column of mud and water in said well casing with the volume of water in the second column exceeding the volume of mud in the first column, said columns being parallel to and in fluid communication with each other, equalizing said columns to provide hydrostatic heads in said columns in excess of the bottom hole pressure of the well, replacing the mud in the first column with water, pumping cement into said first column and conducting the water from the first column to a point adjacent the perforations, pumping fluid into said first column after the cement, conducting the cement from the first column to said point adjacent the perforations, forcing a sufficient amount of said cement into the perforations to seal the perforations, pumping mud into the second column, conducting the pumped mud in the second column into contact with the cement to remove excess fluid cement up the first column, and then displacing the pumped mud with water after the cement has set in said perforations.

2. A method for cementing a high bottom hole pressure well provided with a perforated casing in a stratum pierced by said well and having a tubing arranged therein with its lower end located above said stratum without contaminating said stratum with mud which comprises forming first and second columns of fluid in said well casing, the lower end of the second column being closed, said columns being parallel to and in fluid communication with each other and providing hydrostatic heads in said columns less than the bottom hole pressure of the well and at least said first column containing a clean fluid, closing the lower end of the first column, releasing pressure from the first and second columns, opening the lower end of said first column, pumping cement into said first column and conducting said clean fluid from the first column to a point adjacent the perforations, pumping fluid into said first column after the cement, conducting the cement from the first column to said point adjacent the perforations, forcing a sufficient amount of said cement into the perforations to seal the perforations, pumping fluid into the second column and conducting the pumped fluid into contact with the cement to remove excess fluid cement up the first column, and then displacing the pumped mud after the cement has set in said perforations.

3. A method for cementing a high bottom hole pressure well provided with a perforated casing in a stratum pierced by said well and having a tubing arranged therein with its lower end located above said stratum without contaminating said stratum with mud which comprises forming first and second columns of fluid in said well, said columns being parallel to and in fluid communication with each other and at least said first column containing clean fluid, providing hydrostatic heads in said columns less than the bottom hole pressure of the well, plugging

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the lower end of the first column, releasing pressure from said columns, unplugging the first column, pumping cement into said first column and conducting said clean fluid from the first column to a point adjacent the perforations, pumping fluid into said first column after the cement, conducting the cement from the first column to said point adjacent the perforations to seal the perforations, pumping fluid into the second column, and then conducting the pumped fluid into contact with the cement to remove excess fluid cement up the first column.

4. A method for cementing a high bottom hole pressure well provided with a perforated casing in a stratum pierced by said well and having a tubing arranged therein with its lower end located above said stratum without contaminating said stratum with mud which comprises forming a first and a second column of fluid in said well casing, said columns being parallel to and in fluid communication with each other and at least said first column containing clean fluid, the lower end of the second column being closed, providing hydrostatic heads in said columns less than the bottom hole pressure of the well, closing the lower end of the first column, releasing pressure from said columns, opening the lower end of the first column, pumping cement into said first column and conducting said clean fluid from the first column to a point adjacent the perforations, pumping fluid into said first column after the cement, and conducting the cement from the first column to said point adjacent the perforations, forcing a sufficient amount of said cement into the perforations to seal the perforations, pumping clean fluid into the second column and conducting the pumped clean fluid into contact with the cement to remove excess fluid cement up the first column, and maintaining a positive pressure on the cement until it is set.

5. A method for cementing a high bottom hole pressure well provided with a perforated casing in a stratum pierced by said well and having a tubing arranged therein with its lower end above said stratum without contaminating said stratum with mud which comprises circulating a clean fluid down the tubing and up the annulus between the tubing and casing, closing the annulus between the tubing and casing at a point adjacent the lower end of the tubing, forming a first and a second column of clean fluid in said casing, one of said columns being in the tubing and the other in the annulus, providing hydrostatic heads in said columns less than the bottom hole pressure of the well, closing the lower end of the first column, releasing pressure from the two columns, opening the lower end of said first column, pumping cement into said first column and conducting said clean fluid from the first column to a point adjacent the perforations, pumping fluid into said first column after the cement and conducting the cement from the first column to said point adjacent the perforations, forcing a sufficient amount of said cement into the perforations to seal the perforations, pumping fluid into the first column and then conducting the fluid in the first column into contact with the cement to remove excess fluid cement up the first column.

6. A method in accordance with claim 5 in which the clean fluid comprises water.

7. A method in accordance with claim 5 in which the clean fluid comprises oil.

8. A method for cementing a high bottom hole pressure well provided with a perforated casing in a stratum pierced by said well and having a tubing arranged therein with its lower end located above said stratum without contaminating said stratum with mud which comprises forming a first column of fluid and a second column of fluid and clean fluid in said well casing with the volume of clean fluid in the second column exceeding the volume of fluid in the first column, said columns being parallel to and in fluid communication with each other, replacing the fluid in the first column with clean fluid, pumping cement into said first column and conducting the clean fluid from the first column to a point adjacent the perforations,

pumping fluid into said first column after the cement, conducting the cement from the first column to said point adjacent the perforations, forcing a sufficient amount of said cement into the perforations to seal the perforations, pumping fluid into the second column, conducting the pumped fluid in the second column into contact with the cement to remove excess fluid cement up the first column, and then displacing the pumped fluid after the cement has set in said perforations.

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