April 28, 1964 W. P. ORR 3,130,783

CEMENTING WELL PIPE IN STAGES

Filed Aug. 2, 1962 2 Sheets-Sheet 1

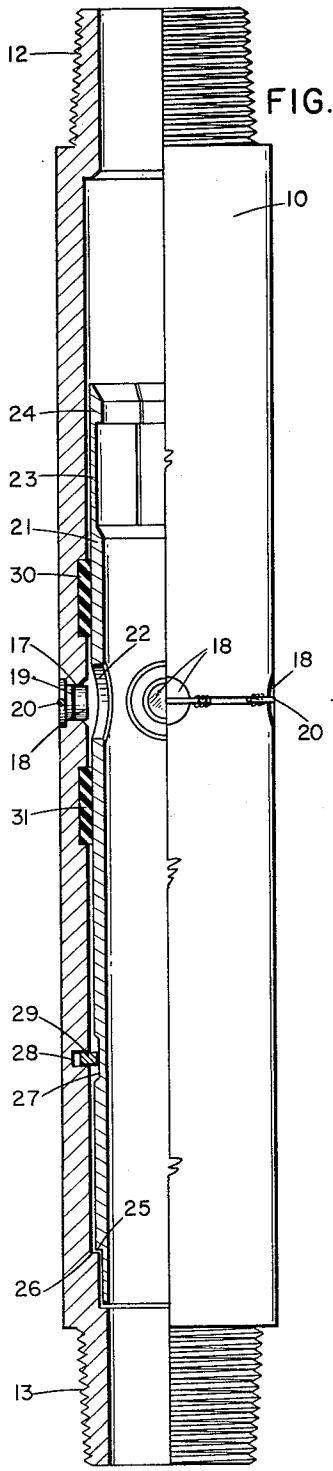


FIG. 1.

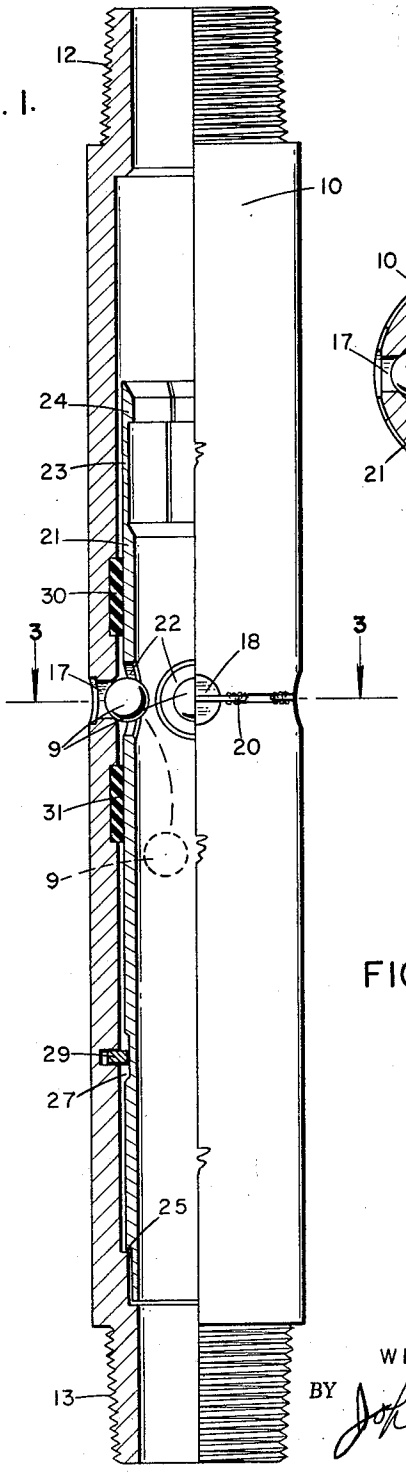


FIG. 2.

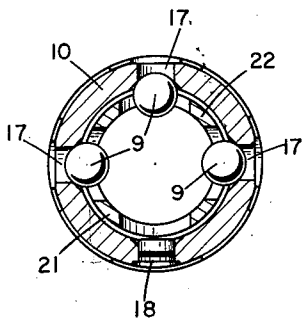


FIG. 3.

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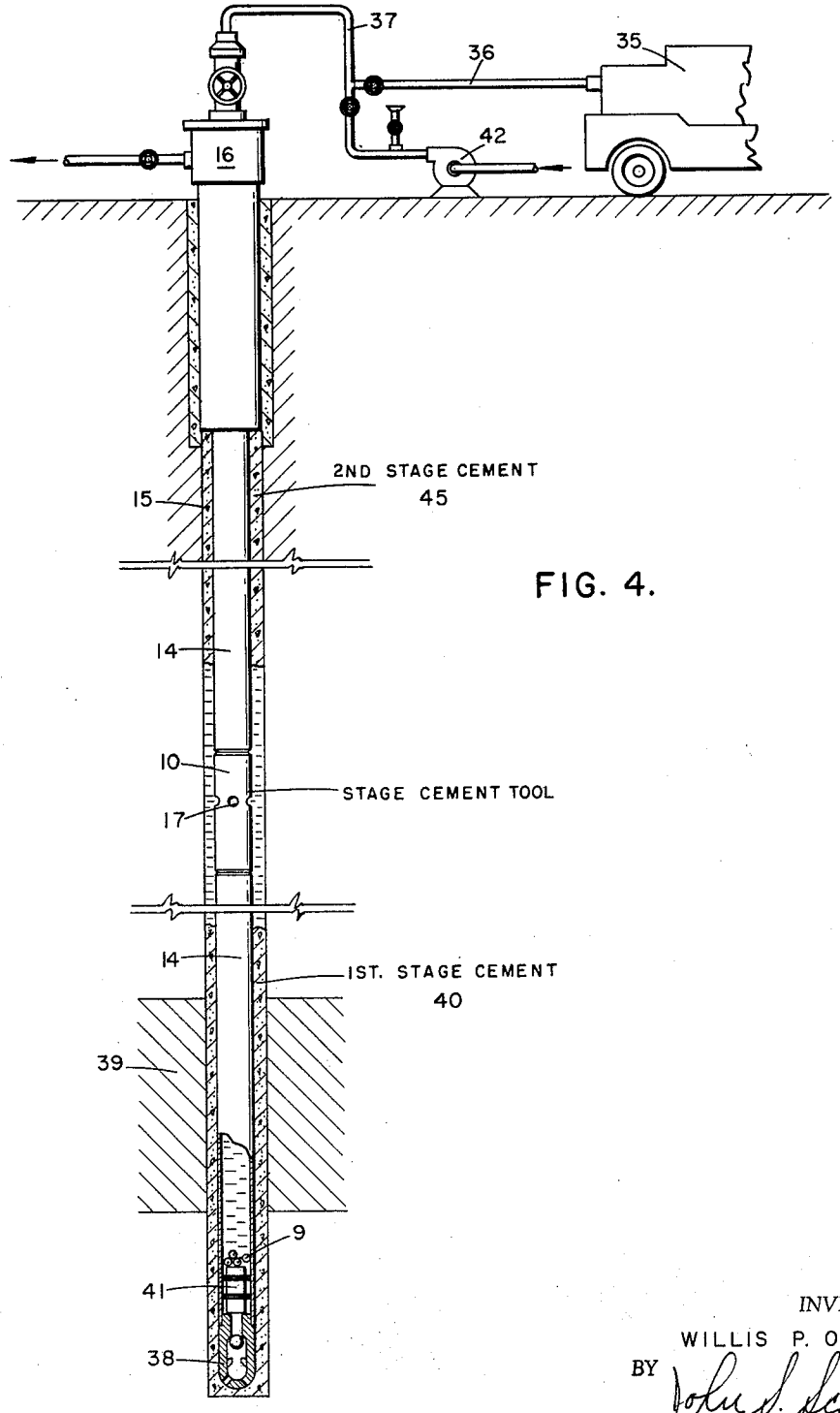


FIG. 4.

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United States Patent Office 3,130,783 Patented Apr. 28, 1964

3,130,783

CEMENTING WELL PIPE IN STAGES

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Filed Aug. 2, 1962, Ser. No. 214,300
2 Claims. (Cl. 166—26)

This invention concerns apparatus for use in a technique for cementing well pipe in a borehole in two or more stages, and in particular, it concerns a staging tool or tools arranged along the length of a well pipe in a manner such that carrying out of a stage cementing operation is facilitated.

Stage cementing of well pipe has important advantages in many wells over single column cementing. It reduces the possibility of breaking down a weak formation with the high cementing pressures required to lift a long column of cement; it minimizes cement contamination during long column cementing; it reduces the quantity of cement required when it is desired to cement widely separated or spaced intervals; and it is useful in placing a cement sheath as a substitute for surface casing.

However, these advantages in operations are offset when presently available staging techniques and tools are used, for in these techniques to complete the well after stage cementing operations, it is necessary to drill out cement, plugs, and the stage tool or tools left in the well pipe.

Thus, the staging tool of the invention overcomes disadvantages in the use of available tools by eliminating the necessity of drilling out the tool and by leaving the well pipe full of displacing fluid instead of having a portion of the well pipe filled with cement. In the arrangement of the apparatus, the entire length of the well pipe is accessible for work-over operations.

In known stage cementing techniques also, the rubber plugs used to spot the stage cement remain in the well pipe and are difficult to drill out. In the present technique, no plug is left in the well pipe, and consequently, drilling out of it prior to cementing in the later stages is eliminated.

The staging tool of the invention permits cementing of upper sands; cementing off of a water sand; and placing of cement as a substitute for surface casing.

Thus, a primary object of the present invention is to provide an improved stage cementing tool and a stage cementing technique for use therewith.

In brief, the cement staging tool comprises a tubular housing or mandrel adapted to be arranged in a well pipe and having circular ports or flow passageways therein, each containing fluid pressure releasable plug means initially closing off fluid communication between the interior and exterior of said well pipe through said mandrel and releasable to establish fluid communication between the interior and exterior of said well pipe through said mandrel when sufficient fluid pressure is applied against said plug means from within said well pipe; and longitudinally movable positive closure means arranged within said mandrel adapted to close off fluid communication through said ports after said plug means have been released when in an upper position and adapted to permit fluid communication through said ports after said plug means have been released when in a lower position.

The above object and other objects and advantages of the invention will be apparent from a more detailed description thereof when taken with the drawings wherein:

FIG. 1 is a vertical, partly-sectional view of the staging tool of the invention;

FIG. 2 is a view similar to that shown in FIG. 1, except the plugs shown in FIG. 1 having been released are being replaced with balls to illustrate a step in the operation which assures that all of the ports have opened.

FIG. 3 is a view taken on lines 3—3 of FIG. 2; and

FIG. 4 is a schematic illustration of a typical use of the staging tool of FIGS. 1 to 3.

For a more complete description of the invention, reference now is made to the drawings in greater detail.

As seen in FIG. 1, the staging tool comprises a sub or mandrel **10** provided with threaded end portions **12** and **13** for threadedly connecting mandrel **10** in a well pipe **14** (see FIG. 4), which in turn is supported in a borehole **15** from a wellhead **16**.

Mandrel **10** is provided with a series of (preferably four) laterally spaced-apart circular ports **17** (see FIG. 3 also). Each port initially contains a plug **18** which is provided with a seal **19** for closing off the space between plug **18** and the wall of the port. Plugs **18** are releasably attached to mandrel **10** by means of shear pins **20**. A sliding sleeve valve **21**, having upper and lower positions and a series of laterally spaced-apart openings **22**, each circularly configured and larger than each port **17**, is arranged within mandrel **10** such that each opening **22** is circumferentially or laterally aligned with one of the ports **17**. The upper end of sleeve valve **21** is split to form a plurality of expansible fingers **23**, which have formed thereon latching shoulders **24**. The lower end of sleeve valve **21** is indented to form a square shoulder **25**, which initially rests on a square shoulder **26** formed on the interior wall of mandrel **10**. Sleeve valve **21** is notched above shoulder **25** and below openings **22**, as at **27**. Also, the inner wall of mandrel **10** is slotted above shoulder **26**, as at **28**, and a square shouldered snap ring **29** is arranged in the slot. When sleeve valve **21** is in its lower position, as seen in FIGS. 1 and 2, notch **27** is adjacent slot **28**, and openings **22** and ports **17** are vertically aligned. Sealing elements **30** and **31** are provided on the inner wall of mandrel **10** above and below ports **17**. Snap ring **29** engages beveled shoulder notch **27** when sleeve valve **21** is in its lower position and temporarily locks the sleeve valve in this position. In the upper position of sleeve valve **21**, not shown, square shoulder **25** rests on square shouldered snap ring **29** to permanently lock sleeve valve **21** in this position. Also, in this position, openings **22** are positioned above upper sealing element **30**, which seals off fluid communication between openings **22** and ports **17**.

The operation of a two-stage cementing technique utilizing one staging tool for a well containing only one long pipe string is illustrated in FIG. 4, and this operation now will be described.

To cement the first stage, the well is conditioned as required, and the first stage cement is pumped from cement truck **35** through conduits **36** and **37** into well pipe **14**, which is provided with a conventional cement shoe **38**. A volume of cement sufficient to cement off an interval **39** is pumped down well pipe **14** past the stage tool and through cement shoe **38** and up the annulus between the wall of borehole **15** and well pipe **14**, as indicated at **40**, the predetermined volume of cement being followed by a cement top plug **41** and follow-up fluid pumped by pump **42** through conduit **37** until plug **41** is positioned atop cement shoe **38**, as illustrated. Well fluid in the annulus between the well pipe and the borehole wall **15** is displaced upwardly through the annulus to the earth's surface.

During the first stage cementing, the stage tool is arranged as illustrated in FIG. 1; that is, the sleeve valve is open and releasable plugs **18** maintain the ports **17** in mandrel **10** closed.

The second stage cement slurry is now placed in the annulus by first pumping fluid by means of pump **42** into well pipe **14** by way of conduit **37**, and additional pressure, 1000 to 3000 p.s.i. above the pressure used for the first stage cementing job, is applied to fracture shear

pins 20 of each of the releasable pump-out plugs 18 and flush these plugs from ports 17.

To insure that all of the plugs have been flushed out of ports 17, port closure balls 9 are placed in the fluid circulated down well pipe 14, through openings 22 and one or more of the ports 17 and up the annulus between well pipe 14 and borehole wall 15 to seal off openings 22, which also seals off ports 17. The balls insure that all of ports 17 open. For example, if only two plugs 18 are flushed out, two balls 9 lodge in the two openings 22 aligned with the two ports 17, from which these plugs were flushed, which permits fluid pressure to increase and force release of the remaining plugs. When the balls fill all of the ports 17, the fluid pressure builds up, assuring that all of the pump-out plugs 18 have been flushed out. FIGS. 2 and 3 show three balls positioned in ports 17. When all of the balls are positioned in the ports, fluid pressure on the balls is released, and the balls drop to the bottom of the well pipe 14 (see FIG. 4). FIG. 2 also illustrates a ball (dotted lines) dropping from its position in a port 17.

Once the balls have been removed from their positions in ports 17, the second stage cement slurry from cement truck 35 is pumped through conduits 36 and 37 into well pipe 14 through openings 22 and 17 into the annulus between well pipe 14 and the wall of borehole 15. The desired volume of cement for the second stage designated 45 is followed by displacing fluid pumped into well pipe 14 by means of pump 42. Then while pressure is maintained within well pipe 14, sleeve valve 21 is moved to its upper, closed position by lowering a wire line tool, not shown, into well pipe 14 to adjacent sleeve valve 21 to engage shoulder 24 and raise sleeve valve 21 upwardly until shoulder 25 is latched by snap ring 29. Sliding sleeve valve 21 can be locked in this position, since there is no further need for opening this valve.

By use of this technique the well pipe 14 is only left with cement displacing fluid following the cementing operation. The well pipe is fully open. There are no plugs or tools or cement to drill out for additional cementing stages. The advantages of closing the stage tool by moving sleeve 21 up instead of down are: (1) the tight fitting wiper plug used to displace the first stage cement cannot even inadvertently move sleeve 21 to its closed position; and (2) swabbing operations subsequent to cementing do not tend to open the stage tool by moving sleeve 21 upwardly; the uppermost shoulder in mandrel 10 prevents further upward movement of sleeve 21 when it is in the closed position.

Although in the foregoing description of the invention only the setting of a surface sheath of cement was described, other second-stage cementing operations may be performed. Additionally, although only a two-stage cementing operation using one well pipe and one staging tool was described to illustrate the invention, three or more cementing stages using additional staging tools may be carried out. When more than one staging tool is used, each tool is positioned adjacent the place the cement is to be spotted, and to prevent the upper tool from fracturing shear pins 20 prematurely, the relative strengths of the shear pins of each tool may be increased from the lowermost to the uppermost tools. Also, cementing operations may be carried out using the staging tools in multiple tubingless completions, in which case one or more of the tools would be arranged in each of several strings of casing.

Having fully described the nature, operation, elements, and objects of my invention, I claim:

1. Apparatus for use in stage cementing of well pipe in a borehole comprising: a mandrel adapted to be connected in said well pipe and provided with at least two laterally spaced-apart circular ports; fluid pressure releasable plug means initially secured in each port; a slidable sleeve valve longitudinally movable within said mandrel and provided with at least two openings, each of which is larger than each of said ports; sealing means arranged between said sleeve valve and said mandrel above and below said ports and said openings when said ports and said openings are aligned; said openings and said ports being aligned when said sleeve valve is in a lower position to fluidly communicate the interior of said sleeve and said ports, said sleeve when in an upper position being adapted to close off fluid communication between the interior of said sleeve valve and said port; and stop means on said mandrel adapted to limit further downward movement of said sleeve valve within said mandrel when said sleeve valve is in its lower position; and means for locking said sleeve valve in its upper closed position.

2. A method for use in stage cementing of well pipe in a borehole using apparatus which comprises: a mandrel adapted to be connected in said well pipe and provided with at least two laterally spaced-apart circular ports; a fluid-pressure releasable plug releasably secured in each of said ports; a slidable sleeve longitudinally movable within said mandrel and having at least two openings therein larger than said ports and aligned with said ports when said valve is in a lower position to fluidly communicate the interior of said sleeve and said ports; sealing means arranged between said sleeve and said mandrel adapted when said sleeve is in an upper position to close off fluid communication between the interior of said sleeve and said ports; and means for locking said sleeve in its upper closed position comprising the steps of: pumping fluid into said well pipe and increasing fluid pressure within said well pipe until at least one of said fluid pressure releasable plugs is released and flushed from its port; circulating fluid down said well pipe and through said openings in said sleeve and said mandrel ports and up the annulus surrounding said well pipe; adding balls to said fluid to seal off said ports with said balls after the ports have been opened by flushing out the plugs to assure opening of all of the ports; releasing the fluid pressure to permit the balls lodged in the ports to drop out of them into the bottom of the borehole; pumping a cement slurry into said well pipe and through said openings in said sleeve and said mandrel ports and depositing said cement slurry in the annulus surrounding the well pipe; and then while maintaining pressure in said well pipe moving said sleeve to its closed position to seal off said mandrel ports.

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