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## WELL CEMENTING METHOD

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### ABSTRACT OF THE DISCLOSURE

A secondary cementing procedure applicable to an oil well wherein a plurality of casings have been set therein. Such procedure includes mounting valve means in one of the casing strings and locating such valve means near each of a plurality of producing formations downhole. Opening one of the said valve means in order to provide access from within the casing to the annulus of the well at that vertical location. Also, squeezing a quantity of cement through the open valve means in order to fill voids in the well annulus at that location. The foregoing abstract is not in any manner limiting with respect to this invention but merely is in compliance with present requirements under Rule 72(b).

This invention concerns a method that is applicable to multiple completion of oil wells, in general. More specifically, the method according to this invention relates to a secondary cementing process that is employed in multiple completion operations in order to seal off voids, or channels of fluid communication, between producing formations in an oil well or for whatever reason such a cement seal in the annulus of the well bore may be desired.

In oil well operations where multiple completions are employed, i.e., where a plurality of casing strings are set in the same well so that more than one producing formation may be connected to separate strings of casing (usually in order that the produced fluid may be separately carried to the surface); the cementing of casings into the well is ordinarily carried out by pumping cement down one of the casing strings to be set therein, with sufficient quantity pumped to fill the annulus of the well (surrounding the casings) all the way from the bottom up to above the uppermost producing formation of interest. A similar practice has been carried out as standard procedure for single cased wells. The purpose in either case is to seal the walls of the well so that undesired well fluids are held back. Then by perforating at desired production strata locations the production fluids only are allowed to flow into the casing for transmittal to the surface.

While it might be expected that the same procedure should provide similar results in single cased wells as in the case where more than one casing string is set in the well, it has been found in practice that the cement normally fails to fill all of the space which surrounds the casing strings in multiple completion wells sufficiently to provide adequate seal against undesired fluid flow either from other strata in the well or between one producing stratum and the next. Consequently, it has been necessary to apply an additional application of cement so as to fill the voids and channels in between desired producing formations.

Prior to this invention, in order to carry out the additional or secondary cementing operations just mentioned, it was necessary to go through a lengthy and costly process of perforating one of the casing strings, with an oriented perforating tool so that the other casing strings are not perforated at the same time. One reason

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that such prior procedure was so expensive and time consuming was that each time a secondary cementing operation was carried out, it involved the use of a small diameter tubing string for pumping the cement slurry to the perforations in order that it could be "squeezed" into the annulus at that location. Then following such a squeeze cementing operation at one location, the small diameter tubing had to be removed completely from the casing, in order to provide sufficient space for inserting and lowering once more an oriented perforating gun for perforating the casing at the next higher location prior to proceeding with a squeeze cementing operation there.

Consequently, it is an object of this invention to provide a relatively simple yet completely effective method for squeeze cementing a plurality of casings in a multiple completion well. The method involves the mounting of valve means in at least one of the casing strings so that there are controllable openings at desired locations adjacent to each of the producing formations in the hole. Then by manipulating these valve means, in accordance with the invention the secondary or squeeze cementing operations may be carried out with a minimum of time, effort and expense involved.

Another object of the invention is to provide a superior secondary cementing method for use in connection with multiple completion wells. The method is such that a plurality of squeeze cementing operations may be carried out in sequence, operating from one of the plurality of casing strings and completing an effective squeeze cementing procedure at each location without any additional trips in and out with the small diameter tubing or with operating tools, e.g., an oriented perforator, into and out of the hole.

Briefly, the invention concerns a method that is applicable to the multiple completion of a well having a plurality of producing zones therein. Furthermore, the well under consideration has a plurality of casing strings set therein; and it has had a primary application of cement which is made to extend over at least that length of the well including said producing zones. The invention concerns a secondary cementing procedure which comprises the steps of first mounting valve means in at least one of said casing strings so as to be located near each of said producing zones. The procedure also comprises opening one of said valve means, and squeezing a quantity of cement through said open valve means in order to seal off said well from vertical flow of fluid within the annulus thereof surrounding said casing strings.

Again briefly, the invention relates to a method in connection with multiple completion of a well having a plurality of producing zones therein and wherein a plurality of casing strings are set in the well. In addition, there is a primary application of cement that is made to extend over at least the length of the well including said producing zones. The invention is particularly concerned with a secondary cementing procedure, which comprises, among others, the step of mounting valve means in one of said casing strings at locations such that each valve means will be located just below one of said producing zones. It also comprises the step of running a tubing string in said one casing string with a valve-means opening tool attached at the lower extremity of the tubing string and having a tail pipe attached for extending a short distance below the opening tool. Also, it comprises the step of raising said tubing string to move said opening tool back through the lower-most of said valve means so as to open same, stopping with the open end of said tail pipe adjacent to said valve opening. In addition it comprises the step of pumping a cement slurry down said tubing string and out said tail pipe until pres-

sure builds up to a predetermined squeeze-pressure amplitude. Finally, it comprises the steps of holding said squeeze-pressure while reversing out said cement slurry above the open end of said tail pipe, and continuing to hold said squeeze-pressure until said cement slurry has set.

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 inventor of carrying out the invention, and in connection with which there are illustrations provided in the drawings, wherein:

The FIGURE 1 drawing illustrates a schematic cross-sectional view of that portion of a well having a plurality of producing formations and with a multiple set of casing strings cemented into place for a multiple completion of the well; and

FIGURE 2 illustrates the same schematic cross-sectional view as FIGURE 1 somewhat reduced in size but with a wire line supporting the operating tool for the valve means employed.

Thus, the FIGURE 1 drawing illustrates schematically a well 11 that penetrates a plurality of producing formations 12, 13 and 14. The well 11 has been completed with a plurality of casing strings 17, 18 and 19 therein. These casing strings have been set in the well by a primary cementing operation so that the well 11 has been filled with cement 22 extending from the bottom of the hole up to well above the top of the uppermost producing formation 12.

It is to be noted, however, that during the primary cementing operation, i.e., when the cement 22 was pumped into the well, it had a tendency to leave voids such as the open spaces 23 shown. These voids are probably caused by various factors, among which is the fact that the casing strings, as they are set in the hole, become twisted and slightly buckled. This means that when the cement slurry rises in the annulus surrounding the casing strings, channeling tends to take place leaving extensive voids or open channels which may and often do reach from one producing formation to the next.

In order to fill these spaces or voids at locations in the vicinity of each of the producing formations so as to seal off and stop fluid flow communication between formations within the hole, a batch of cement (e.g., the cement 26 illustrated) is introduced and squeezed into place so as to completely fill and adequately seal the hole at this point. It will be appreciated that the casing 17 is maintained full of fluid 27 (water or drilling fluid) so that the batch of cement slurry 26 tends to flow out through openings provided in the casing and into any voids encountered.

In order to provide for the flow of the cement slurry which is added during a squeeze cementing operation, from within one of the casing strings, e.g., casing string 17, and emanating at the location in the well where it is desired to have the cement flow out to the surrounding annular space within the hole 11; there must be openings provided through the walls of the casing string 17. In accordance with this invention such openings are provided by having a valve means 29 (that is schematically illustrated) mounted in the casing string 17 so as to be located at a desired level relative to the producing formation 14. Similarly, there are additional valve means 30 and 31 mounted in the casing string 17 at locations so as to be just below each of the other producing formations 13 and 12, respectively, which are illustrated.

It is to be noted that the structure of the valve means employed is not material to the invention and any feasible type of valve structure which may be mounted as part of the casing string, could be employed. For example, it is preferred that a commercil instrument known as a sliding side-door tool (An Otis Engineering Corporation "Type A Otis Sliding Side-Door"—see page 4331 of the 1960-61 edition of "Composite Catalog of Oil Field Equipment and Services," published by World Oil, a Gulf

Publishing Company publication, P.O. Box 2608, Houston 1, Texas) be employed and mounted integrally in the tubing string at the desired locations. In this manner it is feasible to employ a complementary commercial tool (an Otis Engineering Corporation "Type B Otis Positioning Tool"—see page 4360-B of about noted "Composite Catalog") for operating the sliding side-door valves. Such an operating tool for opening the slide door structure of the valves 29, 30 and 31 illustrated, is schematically indicated by the structure which has reference numeral 34 applied thereto.

As the illustration indicates, the operating or positioning tool is attached to a tubing string 35 that has a short additional pipe or extension 36 commonly called a "tail pipe." Such tail pipe is attached below the tool 34 to act in a manner that will be described later. This tail pipe may have a smaller diameter than the remaining portion of the tubing string 35 or it may be the same size. The function of a tail pipe for cementing operations is well known, but briefly in this instance, such an extension below the operating tool structure 34 is employed so as to insure that none of the cement remains in contact with the tool itself after the injection and during the setting period in order that the tool should not become struck from cement deposits.

It is pointed out that while the FIGURE 1 illustration shows the tubing string 35 having the tool 34 attached thereto for opening the valve means elements 29, 30 and 31, it is not necessary for carrying out the method according to this invention to have the tool 34 attached to the tubing string. Thus, as illustrated in FIGURE 2 the positioning tool could be supported on a wire line 40 if desired, and the steps according to this invention would be carried out with the only difference being that involved in the manipulation of the tool 34 separately from the application of cement slurry during the squeeze cementing step.

It is pointed out that other types of valve structure might be employed instead of the preferred Otis type equipment described above. For example, there are several different structures described in issued United States patents, i.e., see No. 2,223,442, E. V. Crowell, Dec. 3, 1940 and No. 2,438,992, R. O. Childers, Apr. 6, 1948.

In order to clarify and fully define the invention, it is here emphasized that the invention is particularly concerned with a secondary cementing process. Such secondary cementing follows the primary cementing job that has been previously completed to set the plurality of casing strings in the well. Thus, prior to the carrying out of the steps of this invention, there will have been involved the activities and structural elements that go along with setting up a multiple completion for a well, i.e., a plurality of casing strings will have been set in the well. Such casing strings, may, if desired, all be full length extending substantially to the bottom of the well. Or, they may be different lengths with each casing string extending only somewhat below a particular producing formation that has been found to exist (as the well was drilled or thereafter). It may be noted that where feasible it is preferable to have all of the casing strings extend the full depth, in order that should one of these casing strings become inactivated it may then be possible to provide connections to another one of the strings as an alternative and cure the defect. In any event the primary cementing job will have been completed in an expected or standard manner by pumping a sufficient quantity of cement slurry down a casing string (which extends substantially to the bottom of the well) with a bottom hole plug inserted on the top of the column of cement slurry. Thus, after the cement has been pumped out the bottom of the casing string and up into the annulus which surrounds the casing strings in the well, it will extend to the desired height up in the well. This procedure ensures that before any contaminating fluid is pumped out with the cement slurry, the plug riding on top thereof will close

the lower end of the casing string and the cementing operation will thereafter be completed as soon as the cement has had ample time to set.

It has been discovered, as has already been mentioned above, that when such primary cementing operation is carried out with a multiple completion well the result is never one hundred percent tight in providing a cement seal around all of the casing strings in every case. Apparently in a rather high percentage of the cases there are substantial voids or channels which form as the cement is applied during the primary cementing operation, and it is these openings or channels of communication between different producing formations that it is desired to close so as to isolate the producing formations from one another. Prior to this invention, in order to provide such isolation it was the practice to perforate one of the casing strings so as to have passageways for the application therethrough of the secondary cement slurry to be squeezed into the spaces thus existing, and such perforation was expensive both in time and equipment.

In view of the foregoing, it will be appreciated that the invention relates to a secondary cementing procedure which involves applying and squeezing cement into an already cemented well, where a plurality of casings have been set therein. Included in the steps of the method according to the invention are the following, but not necessarily in the order stated.

Step 1: mounting valve means in at least one of the plurality of casing strings with such valve means located so as to be positioned near each of the producing zones in the well. Obviously, such valve means must be mounted as part of the casing to which they are attached, prior to introduction and cementing in place of the plural casing strings in the well.

Step 2: opening one of the said valve means in order to provide access from within the casing containing such valve means to the annulus of the well surrounding that and the other of the plural casings therein.

Step 3: squeezing a quantity of cement through the said open valve means in order to create a tight seal which will fill any voids existing in the annulus of the well at the location of the valve means. The accomplishment of the foregoing three steps provides for a secondary cement seal at or near each of the producing formations so that intercommunication within the well from one formation to the next may be avoided.

The invention may also be described in somewhat greater detail, in accordance with a more specific embodiment thereof. The steps involved in this more detailed embodiment of the invention include those set forth below. Here again the invention concerns a secondary cementing operation which follows a previously completed primary cementing of a plurality of casing strings located in the well, and which primary cementing operation has applied sufficient cement to fill the annulus of the well surrounding the plurality of casings, at least as high as the top of the uppermost producing formation of interest.

The steps of this more specific embodiment of the invention may be outlined briefly as follows: Again, the steps recited do not necessarily need to be carried out in the order stated in each instance.

Step 1: mounting valve means in a given one of the plurality of casing strings in the well, so located that when the casing string has been set and cemented in place, each of the valve means will be located just below one of the corresponding plurality of producing zones in the well.

Step 2: running a tubing string in the said one casing string that has the valve means mounted therein through the lowermost of said valve means, and providing a valve means opening tool attached at the lower extremity of such tubing string. There will also be a tail pipe attached to the opening tool end of the tubing string, which tail pipe extends a short distance below the opening tool in order to permit cement slurry that is pumped through the

tubing to be washed clear of the opening tool structure itself.

Step 3: raising said tubing string to move said opening tool through the lowermost of said valve means. This step will open the valve means and should include the stopping of this raising movement with the open end of the tail pipe adjacent to the valve opening thus created.

Step 4: pumping a cement slurry down the said tubing string and out of the open end of the tail pipe until pressure builds to a predetermined squeeze-pressure amplitude.

Step 5: holding said squeeze-pressure while reversing out the said cement slurry above the open end of the tail pipe. This is accomplished by reversing the direction of fluid flow, i.e., pumping water or other hole clearing fluid down the annulus within the casing string surrounding the tubing string, so as to force the cement remaining within the tubing string to be reversed or returned up the tubing string to the surface.

Step 6: continuing to hold the said squeeze-pressure until the cement slurry which has thus been squeezed into place has had ample time to set.

It will be appreciated that as already pointed out above, the purpose of including the tail pipe below the valve opening tool is to avoid any cement remaining and clogging the actions of the tool. In addition, in case the reversing out process of the excess cement, fails to clear all of the cement from the lower extremity of the opening at the bottom of the tubing string; the use of a tail pipe extension renders the structure subject to overcoming the stickage that would thus result. Thus, such stickage may be cured by a so-called bumping off and thus freeing the cemented end of the tail pipe without damage to the tool.

It will be noted that the method according to this invention is applicable to multiple completion wells, and provides a substantial saving in time and expensive equipment which has been involved heretofore in the accomplishment of a secondary squeeze cementing operation.

In addition, an important advantage to be gained by this invention is that due to the fact that the valve-means gives openings all the way around the casing so that the squeeze will be fully effective. Thus, the cement is ejected directly toward the space between casing strings as well as the other directions so that this likely location of voids in the primary cement job, is positively filled.

An advantageous procedure to follow in carrying out the plural secondary cementing jobs for the different producing strata, is to choose that casing string that will be used to produce from the uppermost producing formation, as the string to contain all the valve-means. Then each squeeze job may be done in sequence from the bottom up with only one round trip into the hole for the tubing that is used in the squeeze cementing applications. Also, the plugs of cement formed in the casing string will not need to be drilled out.

While the schematic illustration in the drawing shows the valves located just at the lower edge of each producing formation, it is preferable to actually locate them about ten feet below the production zone to avoid the danger that the squeeze might cause damage to unconsolidated oil sands.

While particular embodiments of the invention have been set forth above 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. In multiple completion of a well having a plurality of producing zones therein and wherein a plurality of casing strings are set and a primary application of cement is made to extend over at least the length of the well including said producing zones, a secondary cementing procedure comprising the steps of mounting valve means in at least one of said casing strings to be located near each of said producing zones, opening one of said

valve means, and squeezing a quantity of cement through said open valve means in order to seal off said well from vertical flow of fluid within the annulus thereof surrounding said casing strings.

2. A secondary cementing procedure according to claim 1 wherein said valve means are all mounted in the same casing string.

3. A secondary cementing procedure according to claim 2 wherein said cement squeezing step is performed a plurality of times in sequence once at each of said valve means locations.

4. A secondary cementing procedure according to claim 2 wherein said valve means opening step is performed with a wire line supported tool.

5. A secondary cementing procedure according to claim 3 wherein said valve means opening steps are performed with a wire line supported tool commencing at the lowermost valve means and progressing upward.

6. A secondary cementing procedure according to claim 2 wherein said valve means opening step is performed with a tool run into the well on a tubing string.

7. A secondary cementing procedure according to claim 3 wherein said valve means opening steps are performed with a tool run into the well on a tubing string.

8. A secondary cementing procedure according to claim 7 wherein said sequence of cement squeezing steps is performed commencing at the lowermost valve means and progressing upward.

9. In multiple completion of a well having a plurality of producing zones therein and wherein a plurality of casing strings are set and a primary application of cement is made to extend over at least the length of the well including said producing zones, a secondary cementing procedure comprising the steps of

mounting valve means in one of said casing strings at locations such that each valve means will be located just below one of said producing zones,

running a tubing string in said one casing string through all of said valve means with a valve means opening tool attached at the lower extremity of the tubing

string and having a tail pipe attached for extending a short distance below the opening tool, raising said tubing string to move said opening tool through the lowermost of said valve means and open same stopping with the open end of said tail pipe adjacent to said valve opening,

pumping a cement slurry down said tubing string and out said tail pipe with pressure build up to a predetermined squeeze-pressure amplitude, holding said squeeze-pressure while reversing out said cement slurry above the open end of said tail pipe, and

continuing to hold said squeeze-pressure until said cement slurry has set.

10. A secondary cementing procedure according to claim 9 further including the additional steps of

raising said tubing string to move said opening tool through the next higher one of said valve means and open same stopping with the open end of said tail pipe adjacent to said valve opening,

pumping a cement slurry down said tubing string and out said tail pipe with pressure build up to a predetermined squeeze-pressure amplitude,

holding said squeeze-pressure while reversing out said cement slurry above the open end of said tail pipe, continuing to hold said squeeze-pressure until said cement slurry has set, and

repeating the foregoing additional steps at each of the remaining valve means locations in sequence.

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