ABSTRACT: Wells may be recompleted at different formations either above or below existing perforations by a process which may include pumping a slug of cement down through the tubing, the well having either oil or water in it, to force the cement out through the existing perforations into the formation. A pressure drop signals when the cement has passed through the perforations. A measured amount of liquid may then be withdrawn from the well so that the formation will force the cement back out through the perforations. The cement may then be allowed to set up to plug the perforations.
3,572,438

1. Field of the Invention
This invention relates to recombination of oil wells, and more particularly it relates to methods for cementing up perforations and reperforating wells in a different arrangement.

2. Description of the Prior Art
The usual completion of an oil well, casing is set through the producing formation and is cemented in place. The casing is then perforated at the producing zone, and the formation may be fractured, by means well known in the art, so that oil will flow from the formation through the perforations into the casing from which it may be produced through tubing extending to the surface. In many cases it becomes desirable to plug off the first producing sand and reperforate at a different zone either above or below the first perforations for additional production from such different zone. A variety of methods are known for plugging perforations and recompleting, some of them being described at pp. 487–508 of Rotary Drilling Handbook, 6th Edition, by Palmer Publications. Most of the prior art methods involve the use of cement to form a plug to close off the old formation. So-called “squeezing” processes provide a very effective plug. However, problems have arisen, particularly where the old and new producing sands are close together, in that it is difficult to place the plug accurately enough to close the old perforations without covering the new zone. It has previously been necessary to have a rig available to place the plugs and to drill out plugs which are positioned wrong.

It has also been extremely difficult and time consuming, and therefore expensive, to plug one formation and then recompleting below that formation, since such an operation has also required the use of a drilling rig to drill out cement within the casing.

SUMMARY OF THE INVENTION
According to the present invention a cement slurry is merely pumped down the well so that it flows through the perforations into the formation. Because of the high viscosity of the slurry, a considerably greater pressure is required to move it into the formation than is required for pumping water or other lower viscosity material into the formation. Thus as soon as all of the cement has been pumped through the perforations and water begins to flow into the formation the pressure in the well drops off. Pumping may then be stopped and a measured amount of liquid withdrawn from the well to allow the formation pressure to force the cement back out through the perforations. Before all of the cement is forced back out, the withdrawal of liquid is stopped and pressure is held on the well long enough for the cement to set up. The casing is then plugged precisely at the point of the old perforations, and the level of the plug can be determined within a few feet.

When it is desired to recomplete the well at a lower zone, the plug can be formed in the perforations and in the formation immediately adjacent the casing, and the cement can be prevented from setting up within the casing itself by providing oil or other inhibiting material in the casing adjacent the perforations so that when the cement is squeezed back out of the formation it will flocculate and fall to the bottom of the well.

BRIEF DESCRIPTION OF THE DRAWING
FIG. 1 is a somewhat schematic vertical sectional view showing an embodiment of the process of this invention at an early stage in the operation thereof;
FIG. 2 depicts the embodiment of FIG. 1 at a later stage of the process;
FIG. 3 depicts the embodiment of FIG. 1 at a still later stage of the process;
FIG. 4 is a schematic view showing another embodiment of the process; and
FIG. 5 is a schematic view showing still another embodiment of the process.

DESCRIPTION OF THE PREFERRED EMBODIMENTS
In FIG. 1 a well casing 10 passes through two oil sands 12 and 14, being perforated at 16 to allow oil from the sand 14 to enter the casing. The casing is provided with a production tubing 18 which is scaled off adjacent its lower end by a packer 20. The tubing extends up the upper end of the casing at the surface and has connected thereto a pipeline 22 provided with a valve 24 and a pressure gauge 26. A conventional Christmas tree will normally be attached to the upper ends of the casing and the tubing. A pressure relief line 28, provided with a valve 30, may be provided to intersect the pipeline 22 between the valve 24 and the well tubing.

FIGS. 1, 2, and 3 depict an embodiment of the process of this invention wherein it is desired to complete the well at a higher level which is very close to the existing producing level. In this embodiment the well, including the tubing and the casing below the packer 20, is thoroughly washed out and then filled with water. The valve 24 is opened and the valve 30 is closed, and a slug of cement slurry 32 is pumped through the line 22 and down through the tubing 18, using, for example, a conventional reciprocating cement pump. The cement is not enclosed but is preceded by and followed by water. As the cement is pumped down into the well, water in the well below it is forced out through the perforations 16 into the formation 14.

As seen in FIG. 2, when the cement reaches the level of the perforations 16 it will be forced out into the formation 14. It will be appreciated that the cement slurry, having viscosity substantially higher than water, will provide a greater resistance to flow into the formation. Thus when the cement begins to flow through the perforations into the formation the higher pressure 26 will register a substantially higher pressure.

At this point the pumping rate is preferably substantially reduced and the pressure gauge is watched carefully. When all, or substantially all, of the cement has been pumped through the perforations into the formation, water can again flow into the formation, and the pressure shown on pressure gauge 26 will be substantially reduced because of the lower pressure required to maintain the flow rate.

According to the invention, it is at this point that pumping into the well is stopped, valve 24 is closed, and valve 30 is opened to bleed off at a relatively slow velocity a measured amount of liquid. As this material bleeds off, as shown in FIG. 3, the formation pressure, or the formation compression reaction, or a combination of these two forces, will force the cement back through the perforations and out into the casing. An amount of liquid is bled out of the tubing which is just sufficient to insure that at least a part of the cement has passed back out into the casing. Of course, there is considerable latitude in the actual amount which can be bled out. Sufficient material may be returned to the casing to form a solid plug in the casing extending up to near the lower part of the zone where it is intended to reperforate. However, insofar as the desired result of plugging the old perforations is concerned, it is only necessary to bleed enough material through the valve 30 to insulate that the cement is filling the perforations. It is only necessary to bleed enough of the liquid from the valve 30 to insure that the cement has returned to the perforations 16 and will set up at this point and thereby close the perforations.

At any rate, it will normally be satisfactory to bleed through the valve 30 a volume somewhat less than the total volume of cement which has been pumped into the well.

Following this bleeding operation the valve 30 is closed and the well is held under pressure long enough for the cement to set up. Perforating guns can then be lowered into the well to the desired location for reperforating the casing.

If a test shows that the plugging was not complete, the foregoing procedure can be repeated.

FIG. 4 illustrates another embodiment of the invention wherein the process is applied to a multiple completion well.
Here the well casing 10 is provided with two sets of perforations 36 and 38 at two producing formations 40 and 42 respectively. Well tubing 44 is provided to produce from the formation 40 and well tubing 46 is provided to produce from the formation 42. A packer 48 is provided around tubing 46 to separate the two producing formations.

In this embodiment of the invention, sand 50 is pumped into the well on top of the packer 48 to protect it from the cement. The cement slug 52 is then handled in the same way as has been described with respect to FIGS. 1, 2, and 3.

FIG. 5 illustrates one embodiment of the process in which it is desired to reperforate at a lower formation 52. In this process the cement is prevented from forming a plug which will hold the casing while still insuring that the cement will set up in such a way as to seal off the perforations 16. To accomplish this material which will inhibit setting of the cement is put into the well. The well may be filled with oil 53, for example, up to about the level of the perforations which are to be sealed off, or the well may be filled with oil all the way to the top. In such an event when the cement is pumped into the well it is preceded by and followed by a quantity of water to protect it from the oil in the well. As the pumping operation proceeds, the oil in the well will be forced out into the formation 16, and then when the initial slug of water reaches the perforations it will be forced out into the formation, followed by the cement, as in the embodiments previously described.

When the pressure has dropped off, showing that all the cement has passed through the perforations into the formation, the pumping is stopped and the valve 30 is opened to drain off the desired amount of liquid, thereby allowing the cement to be forced out of the formation back into the casing. Due to the presence of the oil in the casing, the cement will not set up to form a plug in the casing but will drop to the bottom of the well, as shown at 56, 58 in FIG. 5. Yet because of the water in the formation the cement will be set up in the formation adjacent to perforations 16 to plug these perforations. The well is thereby made ready for reperforating into the formation 52 without the necessity for any intermediate drilling operation to remove a plug in the casing.

One of the primary reasons for failures of plugs used in the prior art for plugging perforations was the inability to achieve a good bond between the cement and the casing wall. In many cases the cement plug would fall below the perforations after it is set up. When the present invention is practiced however, the cement is set up within the perforations and the formation itself, thereby guaranteeing that the formation will be sealed off.

Since the liquid is withdrawn from the well at a relatively slow rate through the valve 30, accurate measurement of the amount of liquid is facilitated, and therefore the plug may be accurately located in the well.

The process of this invention is most easily applied to formations which have a pressure in excess of the hydrostatic head of water. However, the process may also be applied to other formations. For example, where the formation is spread open by the pumping of water into it preceding the movement of the cement into it, the compression reaction of the formation itself will force the cement back out when the pressure is released. In other cases the pressure in the well may be reduced to below the formation pressure by using oil or of oil mixed with gas in the well to reduce the pressure head.

In the case of a formation with extremely high permeability, the process may be performed in two stages, allowing the first slug of cement to set up before pumping in a second slug. If necessary, the first slug may have lost circulation material mixed with it.

The process of this invention was operated in a well in a bay location in Calhoun County, Texas. Operations were conducted through perforations below 9,100 feet in middle Frio age sands. After testing and plugging off sands at 9,400 feet and 9,300 feet, a sand at 9,175—81 feet was perforated and it flowed salt water with a show of oil. The next objective was a sand at 9,146—56 feet, which left a space of only 19 feet for spotting a cement plug. The operation of the present invention was performed but the liquid was withdrawn from the well at a fast rate through a large plug valve. Apparently this caused the plug to drop, since the top of the plug was found to be at 9,185 feet, or 4 feet below the bottom perforation that was being squeezed. Despite this, the formation was found to be effectively sealed off. This was demonstrated by the fact that the 9,175—81 feet perforations were subsequently subjected to a pressure differential to the well bore of approximately 3,300 p.s.i., then to a pressure differential to the formation of approximately 3,400 p.s.i. without any discernable leakage.

Following the foregoing operation, the sand at 9,146—56 feet was perforated and testing commenced. The total elapsed time for the entire operation, not including time waiting for the perforating truck, was 5 hours 15 minutes.

The sand at 9,146—56 feet did not produce in commercial quantities, and the next objective was a sand at 9,126—34 feet, which left a 12-foot interval for spotting the cement plug. The operation of this invention was performed and this time the liquid was withdrawn through a needle valve with careful measurement of recovered liquid. After setting up, the cement plug was found to be at 9,144 feet, 2 feet above the top perforation being squeezed. The well was completed in this upper sand and was put on production.

In this particular well a total of five separate sands were tested without ever unbolting the Christmas tree. The two lower sands had been plugged off by a prior art method since there was adequate space so that it was not necessary to accurately place the plug. However, the entire squeezing, perforating, acidizing, and testing operation covered a period of 7 days and no rig was necessary during any of these operations.

It is apparent that the process of this invention greatly reduces the cost of squeezing off perforations because of the great saving in time alone. Furthermore, it is not necessary to use a rig in any part of the operation. This alone would in many cases save a large portion of the cost of a perforation squeezing job.

Several embodiments of the invention have been shown and described herein. However, after studying the foregoing skilled in the art will conceive of many modifications and variations which come within the scope of the following claims are a part of this invention and are intended to be covered and protected by these claims.

I claim:
1. A method for plugging perforations in a well pipe traversing an underground formation comprising:
pumping a slug of cement down the well pipe and through the perforations and into the formation, said slug of cement being followed by a liquid having lesser viscosity;
continuing said pumping until the pressure in the well pipe drops off, thus signifying that the cement has passed through the perforations;
withdrawing from said well pipe a volume of liquid less than the volume of said slug of cement; and
retaining cement in the perforations and in the formation while allowing it to set up.
2. A method as defined by claim 1 wherein the pumping pressure is monitored, and the flow rate into the well is substantially reduced when the pressure increases, thereby indicating that the cement has reached the perforations and begun to flow through them.
3. A method as defined by claim 1 wherein prior to pumping in the cement, the well is filled with oil up to about the level of the perforations.
4. A method as defined by claim 1, wherein prior to pumping in the cement, the well is substantially filled with oil, and the slug of cement is preceded by and followed by slugs of water to protect the cement from the oil.
5. A method as defined by claim 1, wherein the slug of cement is preceded and followed by water throughout the operation.
6. A method as defined by claim 1 wherein the amount of liquid withdrawn is sufficient to cause some of the cement to
5 be forced back into the well pipe, and including the provision of a liquid which inhibits setting of the cement in the well pipe adjacent to said perforations so that the cement forced back into the well pipe is prevented from setting up.

7. A method for plugging perforations in a well casing having a producing tubing therein comprising:

washing out the tubing and casing with water;

leaving them filled with water;

pumping a slug of cement down the tubing and the casing, with water behind it, the water ahead of the cement passing through the perforations and into the formation;

continuing said pumping until the pressure at the surface drops off, thus signifying that the cement has passed through the perforations and the water behind it has started to pass through;

withdrawing from said tubing at the surface a volume of water less than the volume of said slug of cement; and retaining cement in the perforations while allowing it to set up.

8. A method for completing a well at a different formation, said well having perforations into a first formation, comprising:

pumping a slug of cement down the well and through the perforations into the first formation, said slug of cement being followed by a liquid having lesser viscosity;

stopping said pumping when the pressure in said well drops off;

withdrawing from the well a volume of liquid less than the volume of the cement slug;

retaining cement in the perforations and in the first formation while allowing it to set up; and reperforating the well in the different formation.

9. A method as defined by claim 8 wherein the pumping pressure is monitored, and the flow rate into the well is substantially reduced when the pressure increases, thereby indicating that the cement has reached the perforations and begun to flow through them.

10. A method as defined by claim 8 wherein prior to pumping in the cement, the well is filled with oil to at least the level of the perforations.

11. A method as defined by claim 10, wherein said different formation is perforated at a level below the first perforations.

12. A method for plugging perforations in a well pipe traversing an underground formation, comprising:

pumping a slug of cement, followed by a liquid having lesser viscosity, through the perforations and into the formation;

stopping said pumping in response to a decrease in resistance to flow, signifying that the cement has passed through the perforations;

withdrawing from the well pipe a volume of liquid sufficient to cause a portion, but not all, of said cement to return through said perforations; and retaining cement in the perforations and in the formation while allowing it to set up.

13. A method for recompleting a well at a different level, said well having previously been perforated at a first level, comprising:

pumping a slug of cement through the perforations, said slug of cement being followed by a liquid having a lesser viscosity;

stopping said pumping when the resistance to flow drops off, signifying that the cement has passed through the perforations;

withdrawing from the well a volume of liquid less than the volume of the cement slug;

retaining cement in the perforations while allowing it to set up; and reperforating the well at a different level.