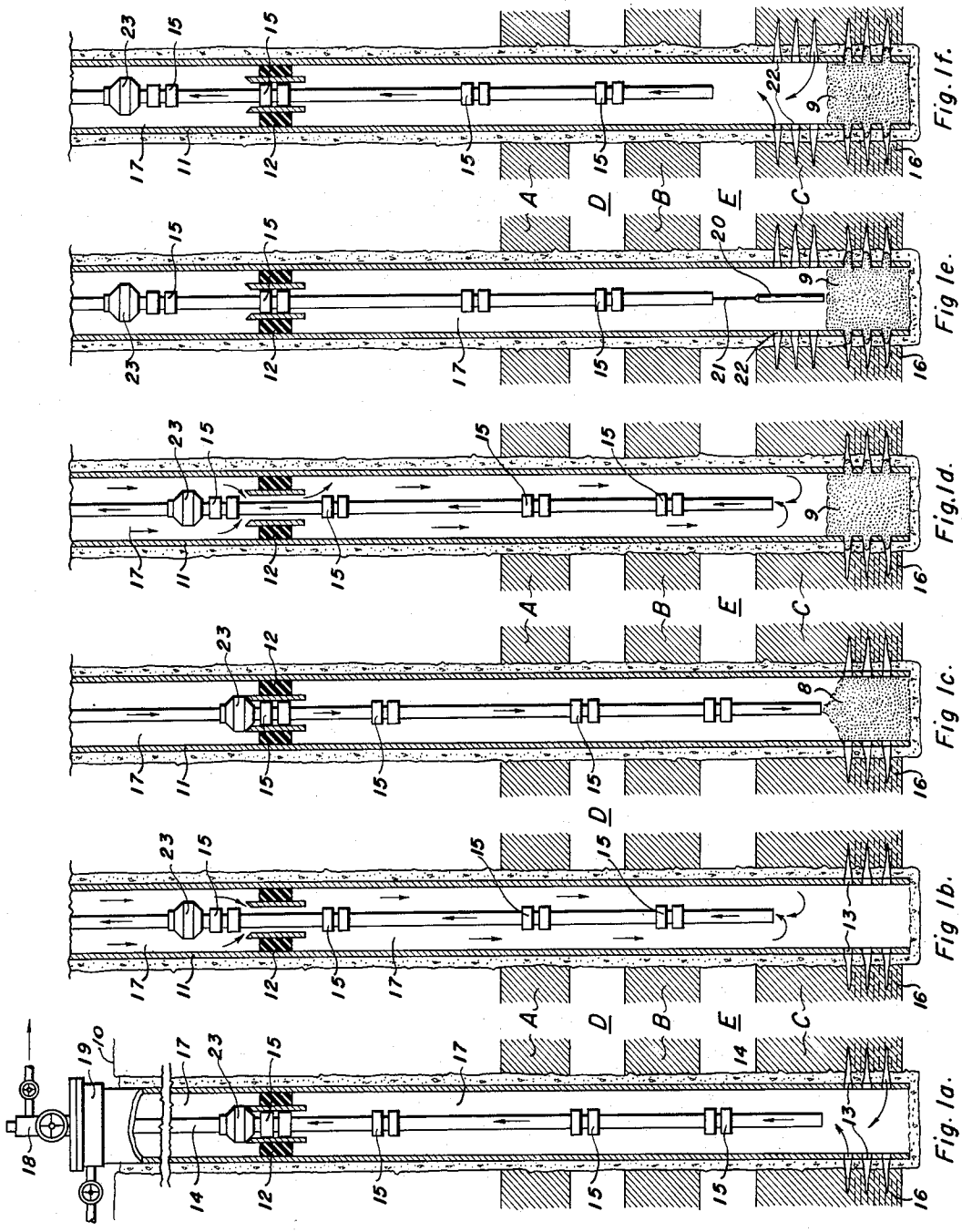
June 19, 1956 L. D. WOODDY, JR 2,751,009

METHOD OF WORKING OVER WELLS

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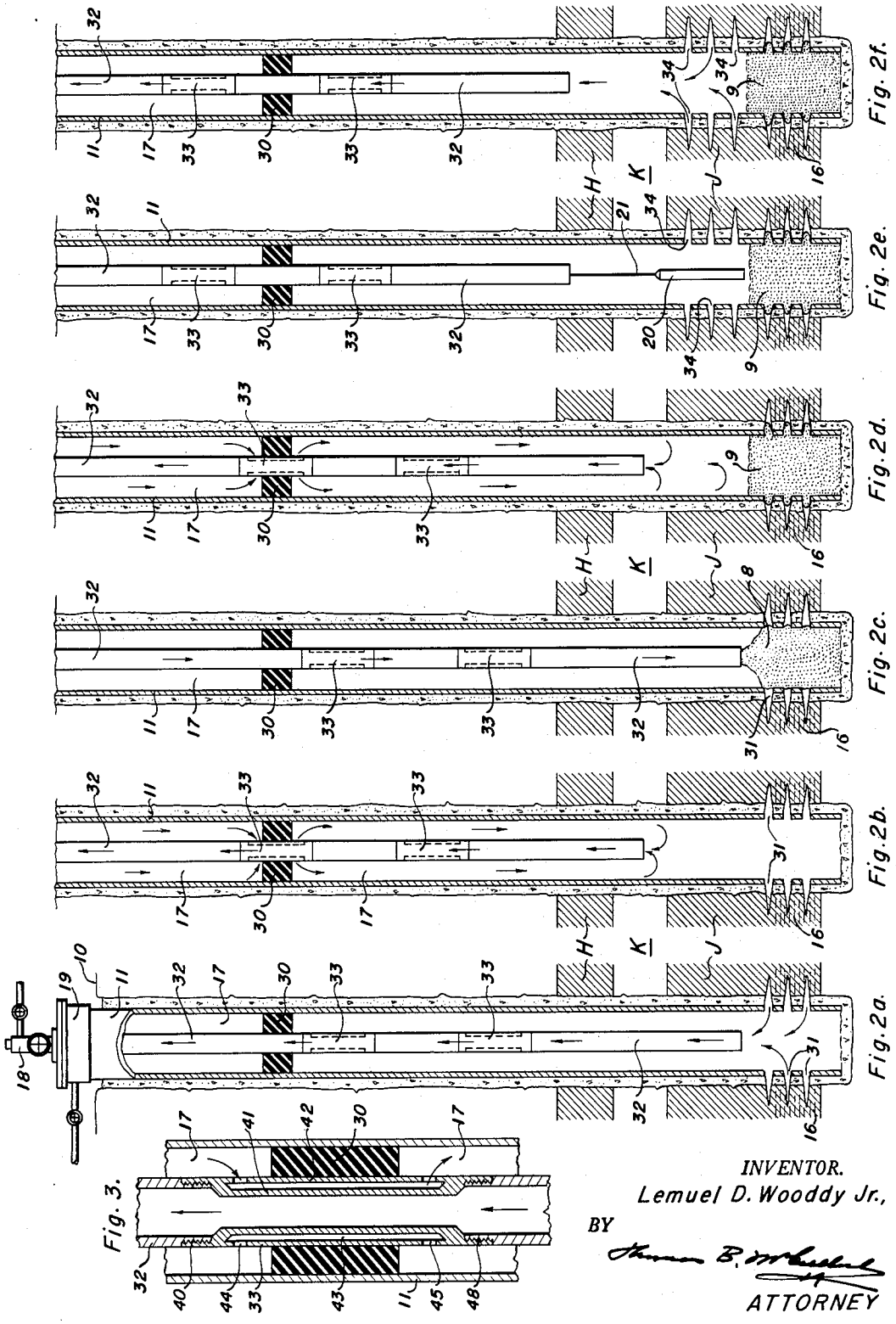


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2,751,009

METHOD OF WORKING OVER WELLS

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13 Claims. (Cl. 166—22)

The present invention is directed to a method for completing and working over wells. More particularly, the invention is directed to a method of working over a cased and tubed well without pulling the tubing. In its more particular aspects, the invention is directed to working over a well to obtain production from a plurality of hydrocarbon productive strata.

The present invention will be briefly described as a method for working over a cased and tubed well penetrating a plurality of hydrocarbon productive strata without removing the tubing from the well which comprises perforating the casing and obtaining production from a hydrocarbon productive stratum until production from said stratum becomes non-commercial. Thereafter the casing and tubing are filled with mud to control the well and a fluid, low water-loss cement is then introduced into the casing through the tubing adjacent the perforations to seal the perforations. Pressure may be applied to the cement to force the cement into and through the perforations to seal the perforations. Thereafter excess fluid cement is removed from the casing and a gun perforator is lowered through the tubing to a level in the casing vertically displaced from the original perforations adjacent a hydrocarbon productive stratum which may be at a different level in the first hydrocarbon productive stratum of the plurality of strata or may be a second hydrocarbon productive stratum. The casing is then perforated at the vertically displaced level and production had from the stratum adjacent the vertically displaced level.

The completion method of the present invention is applicable to wells that are completed in a plurality of hydrocarbon sands such that at a later date a sand may be plugged back or sealed for completion in another interval when water encroachment into the well bore becomes serious.

In the practice of the present invention the tubing which is arranged in the casing and which is not removed, must be made up and lowered into the casing in a prearranged design. For example, the workover program for a plurality of zones or strata would be prearranged such that a thick zone, stratum or sand that will gradually be flooded out by water encroachment will be worked over according to a plan which will depend on electric logs of the well and past history of the reservoir or sand which is to be produced. A suitable tubing packer is first set in the casing above the plurality of zones or strata which are to be produced. The tubing string is then made up and will comprise the usual steel tubing down to a locator sub or shoulder such as an oversized collar which will be made up on the tubing for locating the packer when running in the tubing string. Below the locator sub or shoulder a series of seal nipples and space nipples or a suitable by-pass tool would be arranged at spaced intervals in the tubing string. For example, the seal nipples and space nipples may be made of aluminum and the seal nipples may be placed in the tubing string in pairs, one pair being a unit. The seal

nipples in each unit would be spaced about one foot apart and each nipple would be placed in the tubing string so that when the well is worked over from the bottom zone or interval upwards, for example, the tubing string could be raised to say above a perforated interval in the casing and still have a unit inside the packer. A similar situation would prevail when a by-passing arrangement would be used. This by-passing tool is designed to be run through a suitable packer and permit passage of fluid through the packer in the casing annulus. A series or plurality of by-pass tools would be placed in the tubing string such that the well may be worked over from a bottom zone or interval upwards. The tubing string would be raised say above a perforated interval or zone and have a by-pass tool just below the packer which would allow the well to be mudded up and cement spotted for a workover job by picking up on the tubing.

After a packer has been set in the casing and tubing has been run in with either seal or space nipples or a by-pass tool as integral part of the tubing, recompletion of the well may be accomplished as will be described in more detail. It is contemplated that the well may be worked over or recompleted from a bottom stratum, zone, or interval which is being produced from perforations in the lower portion of the sand or stratum and which is producing a high percentage of salt water. In the present invention recompletion would be arranged in that cement would be used to seal the perforations and allow perforations at a vertically displaced interval in the same sand or stratum or a different sand or stratum.

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

Figs. 1*a* to *f* illustrate one preferred mode of practicing the invention utilizing seal or space nipples;

Figs. 2*a* to *f* describe another preferred mode of the present invention employing a by-pass tool; and

Fig. 3 is a sectional view of a packer and by-pass tool arrangement.

Referring now to the drawing and to Figs. 1*a* to *f*, numeral **11** designates a well casing which has been arranged in a well and cemented in the well as is conventional. The casing **11** penetrates a plurality of hydrocarbon productive intervals or strata such as stratum A, B and C which are separated by non-productive intervals D and E. A packer, such as **12**, is run into the casing **11** and set at a level substantially above the stratum or interval A. This packer may be a Baker model D packer, such as the 415–D illustrated in the Composite Catalogue, 1952–53 edition, page 538. The casing **11** has originally been perforated in stratum C to form perforations **13** in the lower portion of the stratum C to obtain production through the tubing **14** which has been run in with seal and space nipples **15** arranged at intervals in the tubing **14**, as shown.

In Fig. 1*a* the hydrocarbon production from stratum C is becoming non-commercial due to invasion of salt water **16** from the lower portion of the stratum C. In the practice of the present invention the next step is to pick up on the tubing **14** for about 4 feet which will place the first of the seal nipples **15** above the packer **12** and allow the well to be circulated through the annulus **17** as shown by the arrows. Mud would then be circulated down the annulus **17**, by-pass around the packer **15** and then upwardly through the tubing **14** until both the tubing **14** and casing **11** would be filled with mud to control the well. The Christmas tree **18** at the wellhead **19** would then be removed and water, cement, water and mud would then be pumped down into the tubing to spot cement in the area adjacent the perforations **13** and to seal off the interval in sand C from which water encroachment is being had. When about 10 barrels of water are on the outside of the tubing **14** in the casing annulus **17**, the tubing is

again lowered about 4 feet which places the upper of the seal nipples 15 back into the packer 12 closing off circulation in the annulus 17. The rest of the cement, if any, and about 5 barrels of water and mud are then pumped into the tubing 14 until all but about 2 barrels of cement are displaced from the tubing or until the desired squeeze pressure is obtained. The cement 8 is shown in Fig. 1*c* during the squeeze operation to seal the perforations 13.

If the squeeze pressure is not obtained after this operation, the perforations 13 may be cleared of cement by pumping the cement out of the tubing and again raising the tubing about 4 feet and pumping about 5 barrels of water out of the casing and lowering the tubing 14 about 4 feet and pumping the remaining water out of the tubing. The steps as illustrated in Figs. 1*b* and *c* would then be repeated.

Assuming that a successful squeeze job has been obtained on the first trial, the excess fluid cement in the casing 11 is then reverse circulated out by raising up on the tubing 14 such as shown in Fig. 1*d* to place the upper of the seal nipples above the packer 12 and circulating fluid which may be a clean fluid, such as salt water, or mud, down the annulus 17, by-passing the packer 12. The excess fluid cement is then completely removed from the casing 11 or, if desired, a plug of cement, such as 9, is left in the casing 11 to seal off completely the lower portion of the interval C from which salt water encroachment is being encountered.

After the excess fluid cement has been reversed out of the tubing as shown in Fig. 1*d*, the tubing 14 is raised until the bottom of the tubing is about 7 feet above a higher interval which is to be completed. This may be the same sand or stratum C or a stratum such as B as desired. In this particular instance, perforation is to be had again in the stratum C and the excess tubing is removed from the string at the wellhead 19 and a pup joint is installed, if needed, to enable the Christmas tree 18 to be replaced.

After the Christmas tree 18 is replaced, as shown in Fig. 1*e*, a tubing gun 20 is run into the well on a wire line, such as 21, to a level vertically displaced from the original perforations 13 which have been sealed with plug 9. The tubing gun may be one preferably containing shaped charges but may be a gun containing bullets and small enough in diameter to be lowered through the tubing 14. It is to be noted in Fig. 1*e* that the second of the seal nipples are in the packer 12 and the annulus 17 is closed off from circulation.

After the perforations 22 have been formed in the upper level of the stratum C, the tubing gun 20 is withdrawn by means of wire line or cable 21 and production may then be had through perforations 22 in stratum C, the flow being as indicated by the arrows, up the tubing 14 to the wellhead 19 to allow production through the Christmas tree 18.

It is to be noted that in Figs. 1*a* to *f* that a locator sub or shoulder 23 is arranged in the tubing to allow location of the packer 12 on lowering the tubing 14 therethrough.

Since the well may be expected to produce some salt water, it is contemplated that retrievable wire line gas lift valves may be run with the tubing string 14. Such retrievable wire line valves are described in the 1952–53 Composite Catalogue supra on page 1059. During the squeeze cementing operations, the valves may be pulled and blanks inserted in the valve mandrels also shown in the Composite Catalogue supra.

Referring now to Figs. 2 and 3, a casing 11 has been arranged in a well and cemented therein as is conventional practice, the well having been drilled from the earth's surface 10 to penetrate oil sands or strata H and J which are separated by a non-productive interval K. In this modification of the present invention, a packer, such as a wire line packer 30 described on page 947 of the 1952–53 Composite Catalogue supra is run into the well and set at a level above the oil stratum H to allow the well to be worked over as illustrated from the bottom zone upward.

It is to be noted that both oil and water are encountered in the stratum or interval J and the casing 11 has been perforated with perforations 31 and water encroachment is being encountered. From a study of electric logs and past reservoir history, the well may be worked over in a prearranged plan. In this particular instance, a tubing 32 would have suitable by-pass tools 33 arranged at spaced intervals as part of the tubing 32. These by-pass tools are shown in more detail in Fig. 3. Like the mode of Figs. 1*a* to *f*, a suitable shoulder, not shown, in Figs. 2*a* to *f* would be provided in the tubing 32 to locate the packer 30. The by-pass tools 33 would be placed in the tubing string such that as the well is worked over from the interval J upwards to prevent passage of fluid through the annulus 17 by raising the tubing string 32 to put a by-pass tool 33 in the production packer to allow circulation around the annulus for mudding up operations or spotting of cement as will be described. Such arrangement of by-pass tools would enable use of a polish rod or wrap-around tubing hanger described in the Composite Catalogue supra and prevent the necessity of removing the Christmas tree from the well before it has been mudded up and the perforations sealed off as will be described.

In the mode of Figs. 2*a* to *f*, the well has been initially completed by forming perforations 31 with a tubing gun and subsequent workovers are to be performed as will be described.

Referring to Fig. 2*a*, salt water encroachment is being encountered from the lower level in interval J, the flow being shown as indicated by the arrows in Fig. 2*a*. In order to correct this difficulty, the tubing 31 is picked up a sufficient distance to place the first of the by-pass tools 33 in the packer 30 to allow the well to be circulated around. Mud is then circulated to fill the tubing 32 and the casing 11 to control the well, the flow being shown by the arrows in Fig. 2*b*.

In Fig. 2*c*, cement, such as 8, is being spotted to seal the perforations 31 in the lower portion of the stratum J by pumping water, cement, water and mud into the tubing. As indicated before with respect to Fig. 1, when about 10 barrels of water are on the outside of the tubing 32 in the annulus 17, the tubing 32 is lowered until the packer by-pass 33 is completely out of the packer 30 and the rest of the cement, if any, approximately 5 barrels of water, and mud are pumped into the tubing 33 until all but about 2 barrels of cement are displaced from the tubing or until the desired squeeze pressure is obtained, this operation being illustrated in Fig. 2*c*.

In Fig. 2*d* the by-pass tool 33 has been placed in the packer 30 by picking up on the tubing 32 and circulation is had down the annulus 17 and up the tubing 32 in the direction indicated by the arrows to reverse out the excess fluid cement. The Christmas tree 18 is removed to allow the tubing to be pulled up until the lower end of the tubing is above the interval which is to be completed. Excess tubing is removed from the tubing string 32 in the wellhead 19 and a pup joint is installed, if needed, for re-installation of the Christmas tree 18.

After the Christmas tree 18 is reinstalled, the well is perforated as shown in Fig. 2*e* by lowering a tubing gun perforator, such as 20, on a wire line or cable 21 to a level adjacent an upper portion of the stratum J.

It is to be noted that a plug 9 has been formed in the stratum J to seal off the perforations 31 and the plug has been cut by reverse circulation at a point just below the interval to be perforated. After firing the tubing gun which may be of a shaped charge variety to form perforations 34, production is then obtained after removing the tubing gun 20 from the well, as shown in Fig. 2*f*. In this connection it is to be noted that in Figs.

2e and 2f that the by-pass tools 33 are above and below the packer 30 and the annulus 17 is thus closed off.

Referring now to Fig. 3, a packer 30 is shown in a casing 11 with a by-pass tool 33 in the packer 30 allowing flow through the annulus 17 around the packer 30. The by-pass tool 33 may be connected by mating threads 40 to approximately 2½ inch flush joint tubing, such as 32. The by-pass tool 33 is composed of a section 41 which has an inside diameter of approximately 2 inches on the exterior of which there is a sheeting 42 defining with the section 41 an annular space 43 communicating with the annulus 17 by means of ports 44 and 45. The lower end of the by-pass tool 33 may be connected into the tubing string 32 by mating threads 48.

It may be seen that when by-pass tool 33 is in the packer 30 flow may be had around the packer 30 in the direction indicated by the arrows through ports 44, space 43 and ports 45.

The present invention is of wide utility in the oil industry since it allows a well to be worked over without pulling the tubing from the well which would require heavy duty lifting equipment. A service truck with a tubing lifting unit on it may allow the sequence of operations described supra to be performed in about 12 hours at a modest expenditure of labor and effort.

It is to be noted in the practice of the present invention that the tubing is full open allowing the running through of a small tubing gun perforator to form the perforations in the casing as has been described. For example, a full opening two-inch tubing is preferably employed.

In practicing the present invention, a fluid, low water-loss cement, such as described in Salathiel in U. S. 2,482,459 is preferably employed although other low water-loss fluid cements available on the market may be used.

In practicing the present invention, illustrations have been had as to completing in an upper level of the same oil producing sand or stratum. It is to be understood, however, that I contemplate sealing off the perforations in one stratum and then proceeding vertically displaced from the sealed perforations to complete in a second stratum, as desired. Also it is to be understood in the practice of the present invention that the term "strata" or "stratum" contemplates producing intervals in the same zone but at vertically displaced levels.

Also the present invention has been described in a series of operations where production is obtained first from a lower interval and then from an upper interval but I contemplate that production may be had by perforating in an upper interval, sealing the perforations in the upper interval to form filter cakes in the perforations and then reverse out completely the excess fluid cement from the casing and then lowering the tubing to a point above an interval lower down in the casing following which a tubing gun perforator would be lowered through the tubing to perforate in the interval below the original perforations in an upper interval or stratum. Thus my invention is susceptible to many modifications without departing from the spirit and scope thereof.

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 working over a cased and tubed well penetrating a plurality of hydrocarbon productive strata without removing the tubing from the well which comprises perforating the casing and obtaining production from a hydrocarbon productive stratum until said production becomes non-commercial, introducing a fluid, low water-loss cement through said tubing into said casing adjacent the perforations to seal said perforations, moving said tubing longitudinally in said well to provide a passage between the tubing and casing, removing excess fluid cement from said casing, moving said tubing longitudinally in said well to close said passage, lowering a perforator through said tubing to a level vertically displaced from the original perforations in said casing adjacent a hydrocarbon productive stratum, perforating the casing at said vertically displaced level, and obtaining production from said stratum adjacent said vertically displaced level.

2. A method for working over a cased and tubed well penetrating a plurality of hydrocarbon productive strata without removing the tubing from the well which comprises perforating the casing and obtaining production from a hydrocarbon productive stratum until said production becomes non-commercial, introducing a fluid, low water-loss cement through said tubing into said casing adjacent the perforations to seal said perforations, raising said tubing vertically to provide a passage between the tubing and casing, removing excess fluid cement from said casing, raising said tubing vertically to close said passage, lowering a perforator through said tubing to a level vertically displaced from the original perforations in said casing adjacent a hydrocarbon productive stratum, perforating the casing at said vertically displaced level, and obtaining production from said vertically displaced level.

3. A method for working over a cased and tubed well penetrating a plurality of hydrocarbon productive strata without removing the tubing from the well and providing a fluid flow passage between the casing and the tubing which comprises sealing said passage, perforating the casing and obtaining production from a hydrocarbon productive stratum until said production becomes non-commercial, introducing a fluid, low water-loss cement through said tubing into said casing adjacent the perforations to seal said perforations, unsealing said passage, removing excess fluid cement from said casing, again sealing said passage, lowering a perforator through said tubing to a level vertically displaced from the original perforations in said casing adjacent a hydrocarbon productive stratum, perforating the casing at said vertically displaced level, and obtaining production from said stratum adjacent said vertically displaced level.

4. A method for working over a cased and tubed well penetrating a plurality of hydrocarbon productive strata without removing the tubing from the well and providing a fluid flow passage between the casing and the tubing which comprises lowering said tubing to seal said passage, perforating the casing and obtaining production from a hydrocarbon productive stratum until said production becomes non-commercial, introducing a fluid, low water-loss cement through said tubing into said casing adjacent the perforations to seal said perforations, raising said tubing to unseal said passage, removing excess fluid cement from said casing, again raising said tubing to seal said passage, lowering a perforator through said tubing to a level vertically displaced from the original perforations in said casing adjacent a hydrocarbon productive stratum, perforating the casing at said vertically displaced level, and obtaining production from said stratum adjacent said vertically displaced level.

5. A method for working over a cased and tubed well penetrating a plurality of hydrocarbon productive strata without removing the tubing from the well which comprises perforating the casing and obtaining production from a hydrocarbon productive stratum until said production becomes non-commercial, moving said tubing longitudinally to provide a passage between the tubing and casing, filling said casing and tubing with mud to control said well, moving said tubing longitudinally to close said passage, introducing a fluid, low water-loss cement through said tubing into said casing adjacent the perforations to seal said perforations, moving said tubing longitudinally to open said passage, removing excess fluid cement from said casing, moving said tubing longitudinally to close said passage, lowering a perforator through said tubing to a level vertically displaced from the original perforations in said casing adjacent a hydrocarbon productive stratum, perforating the casing at said ver-

tically displaced level, and obtaining production from said stratum adjacent said vertically displaced level.

6. A method for working over a cased and tubed well penetrating a plurality of hydrocarbon productive strata without removing the tubing from the well which comprises perforating the casing and obtaining production from a hydrocarbon productive stratum until said production becomes non-commercial, raising said tubing vertically to provide a passage between the tubing and casing, filling said casing and tubing with mud to control said well, lowering said tubing to close said passage, introducing a fluid, low water-loss cement through said tubing into said casing adjacent the perforations to seal said perforations, raising said tubing to open said passage, removing excess fluid cement from said casing, raising said tubing to close said passage, lowering a perforator through said tubing to a level vertically displaced from the original perforations in said casing adjacent a hydrocarbon productive stratum, perforating the casing at said vertically displaced level, and obtaining production from said stratum adjacent said vertically displaced level.

7. A method for working over a cased and tubed well penetrating a plurality of hydrocarbon productive strata without removing the tubing from the well and providing a fluid flow passage between the casing and the tubing which comprises sealing said passage, perforating the casing and obtaining production from a hydrocarbon productive stratum until said production becomes non-commercial, unsealing said passage, filling said casing and tubing with mud to control said well, sealing said passage, introducing fluid, low water-loss cement through said tubing into said casing adjacent the perforations to seal said perforations, unsealing said passage, removing excess fluid cement from said casing, sealing said passage, lowering a perforator through said tubing to a level vertically displaced from the original perforations in said casing adjacent a hydrocarbon productive stratum, perforating the casing at said vertically displaced level, and obtaining production from said stratum adjacent said vertically displaced level.

8. A method for working over a cased and tubed well penetrating a plurality of hydrocarbon productive strata without removing the tubing from the well and providing a fluid flow passage between the casing and the tubing which comprises lowering said tubing to seal said passage, perforating the casing and obtaining production from a hydrocarbon productive stratum until said production becomes non-commercial, raising said tubing to unseal said passage, filling said casing and tubing with mud to control said well, lowering said tubing to seal said passage, introducing fluid, low water-loss cement through said tubing into said casing adjacent the perforations, raising said tubing to unseal said passage, removing excess fluid cement from said casing, raising said tubing to seal said passage, lowering a perforator through said tubing to a level vertically displaced from the original perforations in said casing adjacent a hydrocarbon productive stratum, perforating the casing at said vertically displaced level, and obtaining production from said stratum adjacent said vertically displaced level.

9. A method for working over a cased and tubed well penetrating a plurality of hydrocarbon productive strata without removing the tubing from the well which comprises perforating the casing and obtaining production from a hydrocarbon productive stratum until said production becomes non-commercial, moving said tubing longitudinally to provide a passage between the tubing and casing, filling said casing and tubing with mud to control said well, moving said tubing longitudinally to close said passage, introducing a fluid, low water-loss cement through said tubing into said casing adjacent the perforations, applying pressure to said cement to seal said perforations, moving said tubing longitudinally to open said passage, removing excess fluid cement from said casing, moving said tubing longitudinally to close said passage, lowering a perforator through said tubing to a level vertically displaced from the original perforations in said casing adjacent a hydrocarbon productive stratum, perforating the casing at said vertically displaced level, and obtaining production from said stratum adjacent said vertically displaced level.

10. A method for working over a cased and tubed well penetrating a plurality of hydrocarbon productive strata without removing the tubing from the well which comprises perforating the casing and obtaining production from a hydrocarbon productive stratum until said production becomes non-commercial, raising said tubing to provide a passage between the tubing and casing, filling said casing and tubing with mud to control said well, lowering said tubing to close said passage, introducing a fluid, low water-loss cement through said tubing into said casing adjacent the perforations, applying pressure to said cement to seal said perforations, raising said tubing to open said passage, removing excess fluid cement from said casing, raising said tubing to close said passage, lowering a perforator through said tubing to a level vertically displaced from the original perforations in said casing adjacent a hydrocarbon productive stratum, perforating the casing at said vertically displaced level, and obtaining production from said stratum adjacent said vertically displaced level.

11. A method for working over a cased and tubed well penetrating a plurality of hydrocarbon productive strata without removing the tubing from the well and providing a fluid flow passage between the casing and the tubing which comprises sealing said passage, perforating the casing and obtaining production from a hydrocarbon productive stratum until said production becomes non-commercial, unsealing said passage, filling said casing and tubing with mud to control said well, sealing said passage, introducing a fluid, low water-loss cement through said tubing into said casing adjacent the perforations, applying pressure to said cement to seal said perforations, removing excess fluid cement from said casing, sealing said passage, lowering a perforator through said tubing to a level vertically displaced from the original perforations in said casing adjacent a hydrocarbon productive stratum, perforating the casing at said vertically displaced level, and obtaining production from said stratum adjacent said vertically displaced level.

12. A method for working over a cased and tubed well penetrating a plurality of hydrocarbon productive strata without removing the tubing from the well and providing a fluid flow passage between the casing and the tubing which comprises lowering said tubing to seal said passage, perforating the casing and obtaining production from a hydrocarbon productive stratum until said production becomes non-commercial, raising said tubing to unseal said passage, filling said casing and tubing with mud to control said well, lowering said tubing to seal said passage, introducing a fluid, low water-loss cement through said tubing into said casing adjacent the perforations, applying pressure to seal said perforations, raising said tubing to unseal said passage, removing excess fluid cement from said casing, raising said tubing to seal said passage, lowering a perforator through said tubing to a level vertically displaced from the original perforations in said casing adjacent a hydrocarbon productive stratum, perforating the casing at said vertically displaced level, and obtaining production from said stratum adjacent said vertically displaced level.

13. A method for working over a cased and tubed well penetrating a plurality of hydrocarbon productive strata without removing the tubing from the well and providing a fluid flow passage between the casing and tubing which comprises sealing said passage, perforating the casing and obtaining production from a hydrocarbon productive stratum until said production becomes non-commerical, unsealing said passage, filling said casing

and tubing with fluid to control said well, sealing said passage, introducing a treating reagent into contact with said perforations and said stratum, unsealing said passage, removing excess treating reagent from said casing, sealing said passage, lowering a perforator through said tubing to a level vertically displaced from the original perforations in said casing adjacent a hydrocarbon productive stratum, perforating the casing at said vertically

displaced level, and obtaining production from said stratum adjacent said vertically displaced level.

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