FIP8011 OR 2,844,205

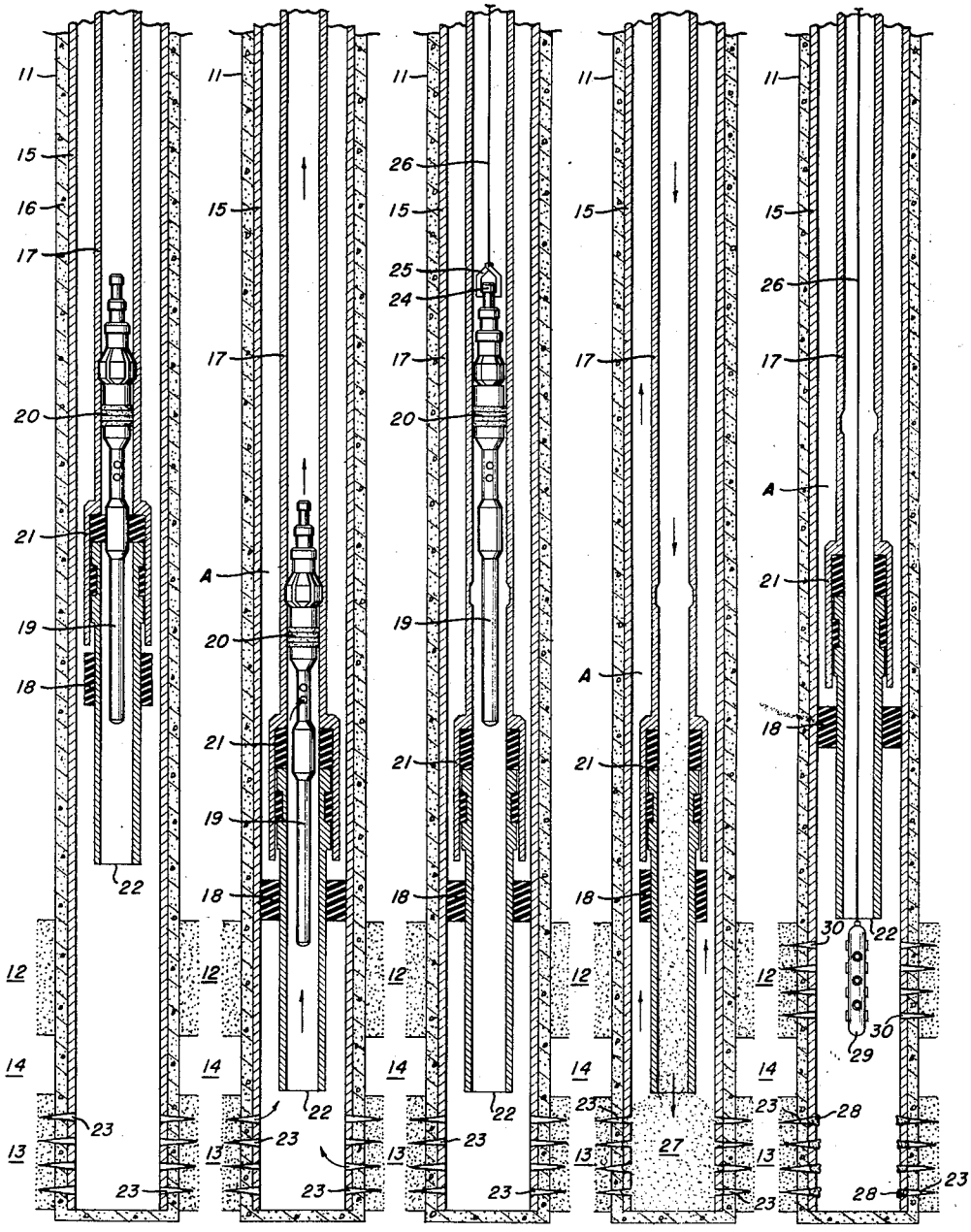
SEARCH ROOM

July 22, 1958 C. M. CAROTHERS 2,844,205

METHOD FOR COMPLETING AND SERVICING A WELL

Filed Dec. 20, 1955 2 Sheets-Sheet 1

FIG. 1. FIG. 2. FIG. 3. FIG. 4. FIG. 5.



104
X101
X106

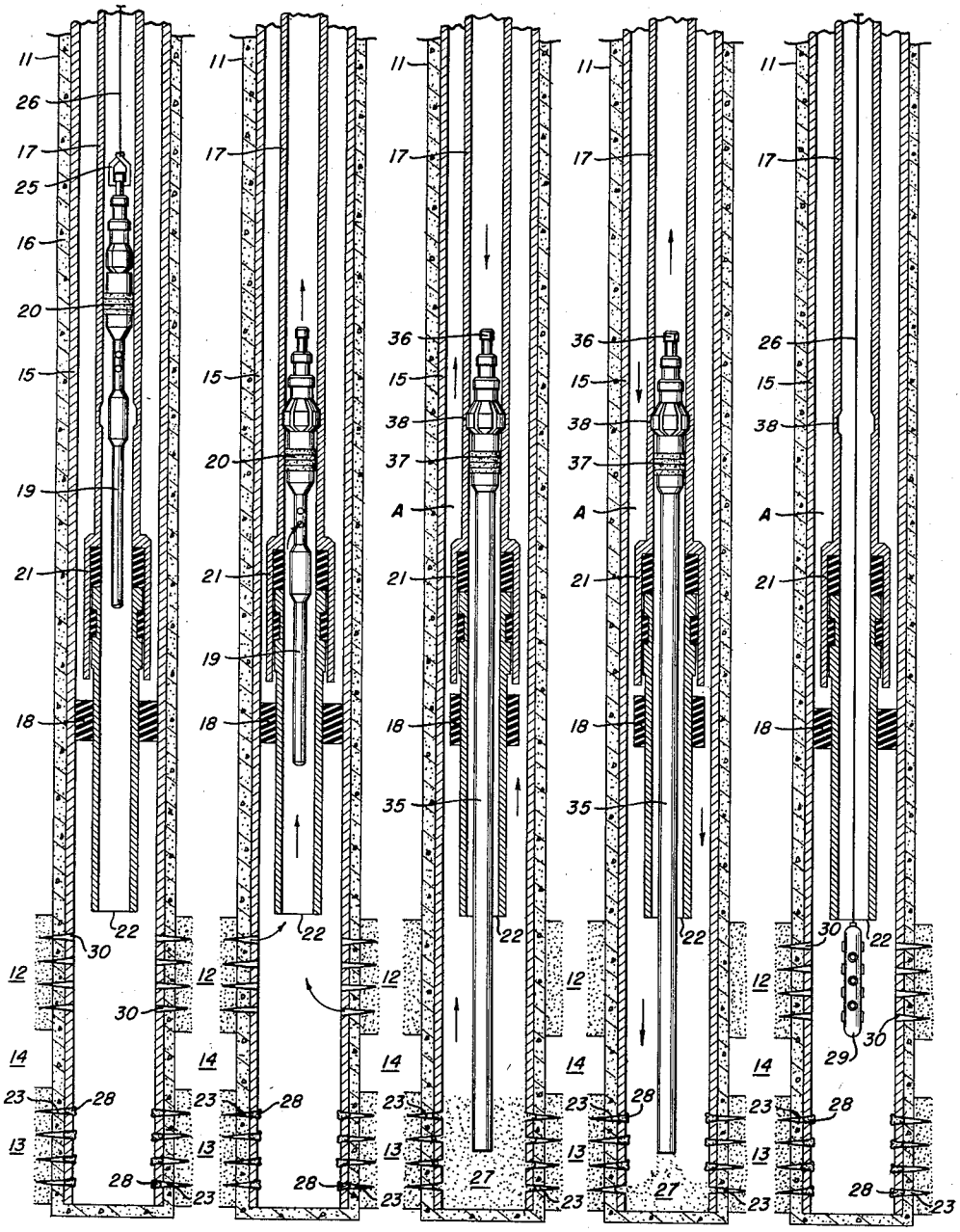
INVENTOR.
Campbell M. Carothers,
BY
ATTORNEY.

July 22, 1958 C. M. CAROTHERS 2,844,205

METHOD FOR COMPLETING AND SERVICING A WELL

Filed Dec. 20, 1955 2 Sheets-Sheet 2

FIG. 6. FIG. 7. FIG. 4a. FIG. 4b. FIG. 5a.



INVENTOR.
Campbell M. Carothers,
BY
ATTORNEY.

United States Patent Office 2,844,205 Patented July 22, 1958

2,844,205

METHOD FOR COMPLETING AND SERVICING A WELL

Campbell M. Carothers, Los Angeles, Calif., assignor, by mesne assignments, to Esso Research and Engineering Company, Elizabeth, N. J., a corporation of Delaware

Application December 20, 1955, Serial No. 554,214

13 Claims. (Cl. 166—4)

The present invention is directed to a method for completing and servicing a well. More particularly, the invention is concerned with a method for testing a well without pulling the pipe from the well. In its more specific aspects, the invention is concerned with a method for testing a well drilled through a plurality of productive intervals without pulling the pipe from the well.

The present invention may be briefly described as a method for completing and servicing a well drilled in the earth to penetrate a plurality of productive intervals and having a casing arranged therein penetrated in a selected of said intervals to provide first perforations. In the present invention a tubing string is lowered in the well having a retrievable pressure recorder arranged therein until the lower end of the tubing is positioned for production at least through the first perforations in the casing. The annular space between the tubing and casing is closed such that pressure is exerted in the tubing and on the pressure recorder. The pressure recorder is retrieved from the well while the tubing is maintained in position whereby the productivity of a selected interval is indicated by the pressure recorded on the pressure recorder. Production is obtained from the well from the selected interval as indicated by the pressure. If pressure is shown by the pressure recorder, then the well is produced until production becomes uneconomical. If no or insufficient pressure is shown by the pressure recorder for commercial production of well fluids then the first perforations are sealed by introducing cement through the tubing into the first perforations to seal same. Thereafter the casing is reperforated to provide second perforations in one of the intervals and the pressure recorder is lowered again in the well and pressure exerted therein from the second perforations. The pressure recorder is again retrieved to determine whether or not production may be had from the second perforations and production is obtained through the second perforations as indicated by the pressure.

In accordance with the present invention, the casing may be reperforated in an interval vertically displaced from the perforated and sealed interval or the casing may be reperforated in the perforated and sealed interval or to perforate more of the productive interval in the same zone which was originally perforated.

The tubing string is lowered in the well casing to position its lower end above the plurality of intervals or it is lowered to position its lower end above the perforated interval. The tubing string may be lowered to position its lower end above the perforated interval and then the tubing is raised after sealing the perforated interval and before reperforating the casing to position its lower end above an interval vertically displaced from the perforated and sealed interval.

The present invention is quite advantageous in that it eliminates unnecessary raising and lowering of the pipe, known in the industry as round trips. In other words, a round trip is the running in of a well pipe in the well and then pulling same out of the well for replacement

of a tool or a section of pipe. In the present invention during completion operations in oil and/or gas wells and the like after the production casing is set, drill stem tests are usually made to evaluate the producing zone. Not infrequently it is necessary to repair a primary cement job, which is cement set around the casing in the well bore, or to perforate more of a productive interval than originally perforated or to reperforate the same interval or to fracture or to acidize a productive interval. Sometimes a combination of any or all of these operations is required which would mean running the pipe in the well and pulling same out of the well many times. Present methods of drill stem testing do not provide a means of cementing and reperforating with the formation testing tool in the well. Thus, it is necessary to pull the formation test tool and then conduct the cementing operation, repull the cementing tools and then reperforate the cemented casing. It will be apparent that considerable rig time is consumed during the numerous round trips of the pipe.

In accordance with the present invention, round trips of pipe are eliminated and wells are completed and serviced while formations are tested selectively without removing the tubing string from the well. Thus the invention is quite advantageous and useful in reducing the amount of time consumed in testing and completing wells and thus allowing the wells to be completed and serviced more cheaply than heretofore. Also, by maintaining the tubing in the well, improved results are obtained in that there is less damage to producing formations than that caused by pulling pipe, tubing, and tools from the well using a fluid foreign to formation fluids inside of the casing to control formation pressure.

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

Figs. 1 to 7 represent a sequential stepwise mode of practicing the invention, and

Figs. 4*a*, 4*b*, and 5*a* illustrate a modified mode of practicing the invention taken in conjunction with Figs. 1 to 7.

Referring now to Figs. 1 to 7, in which identical numerals will be employed to designate identical parts, numeral **11** designates a well bore drilled from the earth's surface, not shown, to penetrate a plurality of productive formations **12** and **13** separated by non-productive formation **14**. Formations **12** and **13** may be sands, strata, zones, or intervals in a productive formation while non-productive formation **14** may be a non-productive interval, stratum or zone in a productive or non-productive formation.

A casing **15** is cemented in the well bore **11** with a primary cement job **16** and a tubing string **17** is run into the well casing **15** provided adjacent its lower end with packer **18** in inoperative position. Arranged in the lower end of the tubing **17** is a pressure recorder device **19** which is provided with a sealing means **20** to allow a seal between the interior wall of the tubing **17** and the interior wall of the pressure recorder **19**. The pressure recorder **19** is a suitable wire line pressure recorder, such as described in U. S. Patent 2,189,919, issued Feb. 13, 1940, in the name of Thomas V. Moore. Other pressure recording instruments available in the industry may be used such as illustrated on page 2720 of the 1952–53 Composite Catalog of Oil Field & Pipeline Equipment.

A valve, such as **21**, is arranged in the tubing **17**. This valve may be a valve or closure member as described in patent application Serial No. 554,215 filed December 20, 1955, for James E. Willingham, Jr. The closure member is operated by manipulation of the tubing by rotation and setting down weight thereon.

The packer **18** is described in Baker Oil Tools, Inc.

bulletin No. 316 printed in the United States of America and may be set by right hand rotation of the tubular string **17** to position the upper packer slips on the tapered member of the packer and in gripping contact with the inner surface of the well casing **15**. Subsequent application of weight, resulting from lowering the tubing string **17** to be supported by the packer slip contact with the well casing **15**, causes deformation of the rubber packing element to form a seal in the annulus between the tubing string **17** and the well casing **15**.

The example shown in Fig. 1 is in the running in position, the pressure recorder device being arranged in the tubing at the well head. In Fig. 2 the packer **18** is in operative position to close the annulus A between the tubing **17** and the casing **15**. The lower open end **22** of the tubing **17** is arranged immediately above the productive interval **13** in which perforations generally indicated by the numeral **23** had previously been formed such as by lowering a gun perforator through the casing **15** and firing same.

In the running in position, as illustrated in Fig. 1, the valve **21** may be in the closed position to maintain the interior of the tubing **17** free of well fluids while in Fig. 2 the valve **21** is opened to allow fluid pressure to be exerted in the tubing **17** and on the pressure recorder **19**, the packer **18** being expanded into sealing position to close the annulus A. Thus fluids may pass up through the tubing **17** and the pressure thereof exerted on the recorder **19**.

After the pressure has been exerted on the recorder **19**, it is retrieved from the well by engaging the fishing head **24** thereof with a wire line fishing tool **25** attached to the lower end of wire line **26** and pulling the recorder device **19** from the tubing **17**, the valve **21** being of a type to allow the recorder **19** to be retrieved from the tubing. The removal of the pressure recorder is shown more clearly in Fig. 3.

After the pressure recorder has been removed as shown in Fig. 3, cement is flowed down the tubing **17** into the casing **15**, the packer **18** being collapsed to allow circulation down the tubing **17** and up the annulus A. Cement, such as cement slurry **27**, is deposited in the casing and in the perforations **23** to seal the perforations and to form the plugs or buttons **28** therein. Thereafter the excess cement slurry **27** is removed from the casing **15** by circulating a washing liquid, such as water, mud, and the like, down the annulus A and causing the excess cement slurry to flow up the tubing **17** and thence from the well.

After the plugs **28** have been formed to seal off the perforations **23** and to seal the zone **13** from the casing, the tubing **17** is raised such that its lower end **22** is above the interval or zone **12**. The packer **18** is expanded to seal off the annulus A and a perforator which may be a bullet gun or shaped charged perforator **29** attached to wire line **26** is lowered through the tubing **17** and positioned in the casing **15** adjacent the interval **12**. The perforator is operated or fired to form perforations **30** through the casing and into the interval **12** and to allow production therefrom.

Thereafter the gun perforator **29** is withdrawn on wire line **26** as shown in Fig. 5 and the pressure recorder device **19** as shown in Fig. 6 is lowered on wire line **26** and again positioned in the tubing **17** as shown in Fig. 7. The sequence of operations, as illustrated in Figs. 2 to 6, inclusive, may then be repeated until a commercial productive interval is located. Thus, in Figs. 2 and 7, the pressure differential from the intervals **13** and **12** is into the well casing **15** and the pressure is exerted on the recorder device **19** with the flow of fluids. This pressure differential into the well bore may be obtained by swabbing, circulation, or by reducing the hydrostatic column of fluid in the well to cause flow into the well bore.

In accordance with the present invention, it is possible to arrange the lower open end **22** of the tubing **17** initially above the intervals **12**, **13**, and **14** and to conduct operations, such as illustrated in Figs. 4 to 5, without raising the tubing.

Referring now to Figs. 4*a*, 4*b*, and 5*a*, the tubing **17** is initially arranged in the well casing **15** as illustrated in Figs. 5, 6, and 7, and it is desired to cement off the perforations **23**. To conduct such operations with tubing **22** in the position as shown in Figs. 4*a*, 4*b*, and Fig. 5*a*, a tubular extension member, such as **35**, is lowered on wire line **26** through the tubing **17** until it extends from the lower open end of the tubing **22** into the region of the casing **15** adjacent the perforations **23**. The tubular extension member **35** has a fishing head **36** and packing **37** and is designed to be supported, anchored and/or sealed in a landing nipple, such as **38**, as illustrated at page 4063 of the Composite Catalog mentioned supra. As shown in Fig. 4*a*, the packer **18** is in the collapsed position and a cement slurry is introduced down the tubing **17** and deposited as a body **27** adjacent the perforations **23** to form plugs or buttons **28** therein. The cement slurry employed in Figs. 4 and 4*a* may suitably be a modified cement, such as described in the Salathiel Patent No. 2,582,459. Other modified cements may suitably be employed.

After the buttons or plugs **28** have been formed in the perforations **23** to seal off the formation or zone **13**, excess cement slurry is circulated from the casing **15** by circulating fluid, such as water or mud, down the annulus A and up through the tubular extension member **35** and thence through the tubing **17** to the wellhead.

Thereafter, as shown in Fig. 5*a*, the packer **18** is expanded to seal off the annulus A and a gun perforator, such as **29**, which may be of the bullet gun or shaped charge type is lowered on the wire line **26** through the open end **22** of the tubing **17** and then fired to form perforations **30** in the casing **15** and in the formation **12**. Thereafter the steps are the same as shown in Figs. 6 and 7, the perforator **29** having been withdrawn from the tubing **17** by wire line **26**.

From the foregoing description taken with the drawing, it will be seen that a method has been provided for testing and completing oil and/or gas wells and the like without requiring the removal of the tubing string from the well. In fact, as shown in conjunction with Figs. 1 to 7, and Figs. 4*a*, 4*b*, and 5*a*, such operations may be conducted without moving the tubing after the running in operation. While it is possible to place the tubing in the well and then run the recorder device on a wire line as shown in Fig. 6, instead of running it into the well when the tubing is run in, as shown in Fig. 1, the operation as described with respect to Fig. 1 eliminates one wire line running operation and, therefore, is to be preferred.

Thus, in accordance with the present invention, a new method is provided for testing selected intervals in an oil and/or gas well without requiring round trips. This method involves running the tubing with the valve closed, as described in Fig. 1, to a depth just above the perforated interval to be tested. The packer is set and the valve is opened to allow the test to be made. After the test has been made the pressure recorder device is retrieved on a wire line. If the pressure recorder device indicates the zone to be non-productive, a squeeze cementing operation may be performed by depositing cement in the casing through the tubing and closing off the casing and exerting pressure through the tubing sufficient to squeeze the cement through the perforations. The cementing operation may be performed, if the well is indicated to be productive, after the interval or zone has become depleted or production therefrom has declined due to water and/or gas invasion. Regardless of when the cementing operation is performed, the excess cement is washed out, either as shown in Fig. 4 or in Figs. 4*a* and 4*b*, the packer reset and a zone reperforated using a tubing type per-

forating gun or perforator of the mechanical type which is lowered through the tubing. The pressure recorder is run into the hole again, pressure differential into the casing is provided by swabbing or reducing the hydrostatic head to cause fluid to flow through the second perforations and the operation repeated until a satisfactory test is obtained.

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 completing and servicing a well drilled in the earth to penetrate a plurality of productive intervals and having a casing arranged therein perforated in one of said intervals, said casing containing a hydrostatic column of well fluids sufficient to prevent flow into the perforated casing and in which round trips of tubing are avoided, which comprises lowering a tubing string in said well casing having a retrievable pressure recorder arranged therein until the lower end of the tubing is positioned for production from at least said perforated interval, the passageway through the tubing being closed at a level above the pressure recorder, whereby the tubing is free of said well fluids, closing the annular space between the tubing and casing and opening the passageway through the tubing, adjusting the pressure in the well such that pressure from said perforated interval is exerted in said tubing and on said pressure recorder, retrieving said pressure recorder while maintaining the tubing in position whereby the productivity of said perforated interval is indicated by the pressure recorded on said pressure recorder, and then obtaining production from said perforated interval as indicated by the pressure on said pressure recorder.

2. A method for completing and servicing a well drilled in the earth to penetrate a plurality of productive intervals and having a casing arranged therein perforated in a selected of said intervals to provide first perforations, said casing containing a hydrostatic column of well fluids sufficient to prevent flow into the perforated casing and in which round trips of tubing are avoided, which comprises lowering a tubing string in said well casing having a retrievable pressure recorder arranged therein until the lower end of the tubing is positioned for production at least through said first perforations, the passageway through the tubing being closed at a level above the pressure recorder, whereby the tubing is free of said well fluids, closing the annular space between the tubing and casing and opening the passageway through the tubing, adjusting the pressure in the well such that pressure is exerted in said tubing and on said pressure recorder, retrieving said pressure recorder while maintaining the tubing in position whereby the productivity of said selected interval is indicated by the pressure recorded on said pressure recorder, obtaining production from said selected interval as indicated by the pressure thereof, sealing said first perforations in said casing, reperforating the casing to provide second perforations in one of said intervals, arranging the pressure recorder in the lower end of the tubing, exerting pressure in said tubing and on said pressure recorder through the second perforations, again retrieving said pressure recorder from the tubing whereby productivity is indicated by the pressure recorded on said pressure recorder, and then obtaining production through the second perforations.

3. A method in accordance with claim 2 in which the casing is reperforated in an interval vertically displaced from the perforated and sealed interval.

4. A method in accordance with claim 2 in which the casing is reperforated in the perforated and sealed interval.

5. A method in accordance with claim 2 in which the tubing string is lowered in the casing to position its lower end above the plurality of intervals.

6. A method in accordance with claim 2 in which the tubing string is lowered to position its lower end above the perforated interval.

7. A method in accordance with claim 2 in which the tubing string is lowered to position its lower end above the perforated interval and the tubing is raised, after sealing the perforated interval and before reperforating the casing, to position its lower end above an interval vertically displaced from the perforated and sealed interval.

8. A method for completing and servicing a well drilled in the earth to penetrate a plurality of productive intervals and having a casing arranged therein perforated in a selected of said intervals to provide first perforations, said casing containing a hydrostatic column of well fluids sufficient to prevent flow into the perforated casing and in which round trips of tubing are avoided, which comprises lowering a tubing string in said well casing having a retrievable pressure recorder arranged therein until the lower end of the tubing is positioned for production through said first perforations, the passageway through the tubing being closed at a level above the pressure recorder,whereby the tubing is free of said well fluids, closing the annular space between the tubing and casing and opening the passageway through the tubing, adjusting the pressure in the well such that pressure is exerted in said tubing and on said pressure recorder, retrieving said pressure recorder while maintaining the tubing in position whereby the productivity of said selected interval is indicated by the pressure recorded on said pressure recorder, obtaining production from said selected interval as indicated by the pressure on said pressure recorder, flowing a cement slurry through the tubing to deposit same in the first perforations, sealing said casing in said perforated interval with said cement slurry, lowering a perforator through the tubing and reperforating the casing to provide second perforations in one of said intervals, lowering the pressure recorder in the tubing and arranging the pressure recorder in the lower end of the tubing, reducing the pressure in the casing to provide a pressure differential into the casing, exerting pressure in said tubing and on said pressure recorder through the second perforations, again retrieving said pressure recorder from the tubing whereby the productivity of the reperforated interval is indicated by the pressure reorded on said pressure recorder, and obtaining production through the second perforations.

9. A method in accordance with claim 8 in which the casing is reperforated in an interval vertically displaced from the perforated and sealed interval.

10. A method in accordance with claim 8 in which the casing is reperforated in the perforated and sealed interval.

11. A method in accordance with claim 8 in which the tubing string is lowered in the casing to position its lower end above the plurality of intervals.

12. A method in accordance with claim 8 in which the tubing string is lowered to posiiton its lower end above the perforated interval.

13. A method in accordance with claim 8 in which the tubing string is lowered to position its lower end above the perforated interval and the tubing is raised, after sealing the perforated interval and before reperforating the casing, to position its lower end above an interval vertically displaced from the perforated and sealed interval.

References Cited in the file of this patent

UNITED STATES PATENTS

2,212,044	Ridley	Aug. 20, 1940
2,347,746	McWilliams	May 2, 1944
2,693,856	Allen	Nov. 9, 1954
2,749,989	Huber	June 12, 1956
2,760,578	Tausch	Aug. 28, 1956