

[54] **OCEAN BOTTOM WELL TUBING VALVE INSTALLATION**

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[52] U.S. Cl. **166/5, 166/224 S, 166/313**

[51] Int. Cl. **E21b 33/035**

[58] Field of Search 166/5, .6, 313, 166/224, 224 S, 226

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[57] **ABSTRACT**

A method for completing an offshore well with tubing strings having full opening valves at the ocean floor or mudline, and one style of apparatus that can be used for carrying out the method. The method generally involves running and setting the tubing strings in a hanger at the ocean floor or mudline, and then continuing the strings to the surface wellhead by means of tubing extensions that are fitted with remotely controllable valves at the lower ends. The tubing extensions are releasably connected to the tubing strings so that the extensions and the valves can be removed and reinstalled as an assembly, such as for servicing or replacing the valves, without also having to remove the tubing strings or their hanger from the well. The described apparatus includes a tie-back adapter for connecting a riser to the innermost casing hanger in an underwater well at the mudline, a master bushing that supports the tubing strings inside the tie-back adapter, and a tie-back mechanism for releasably connecting the tubing extensions to the tubing strings.

14 Claims, 13 Drawing Figures

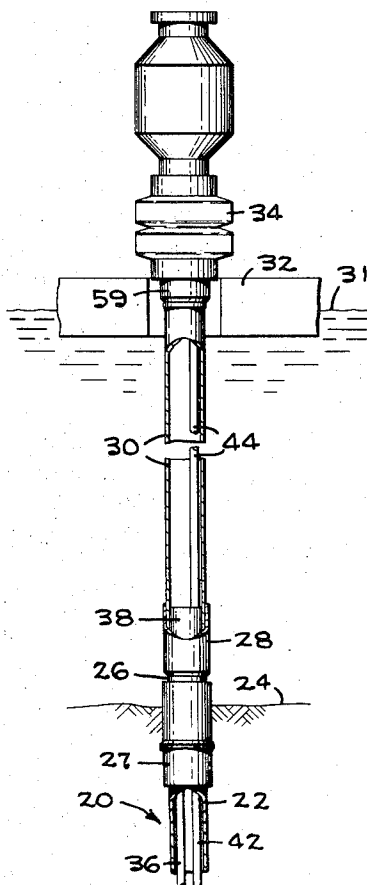


FIG. 3

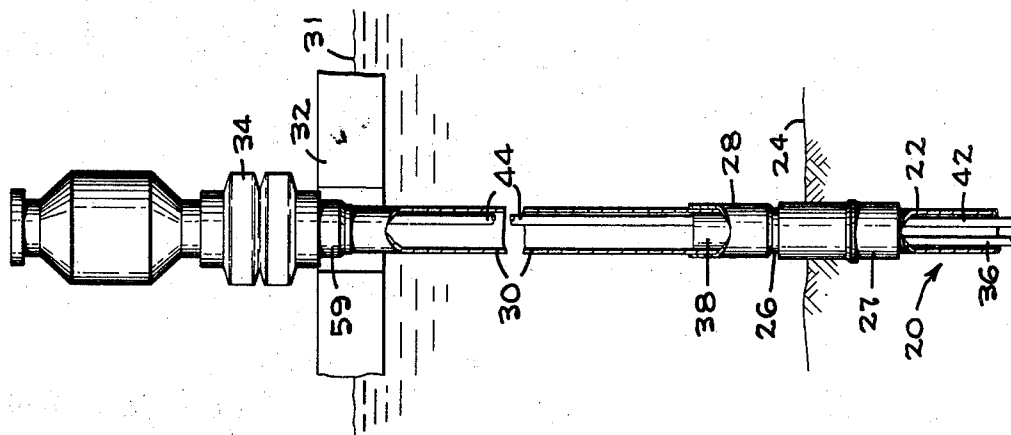


FIG. 2

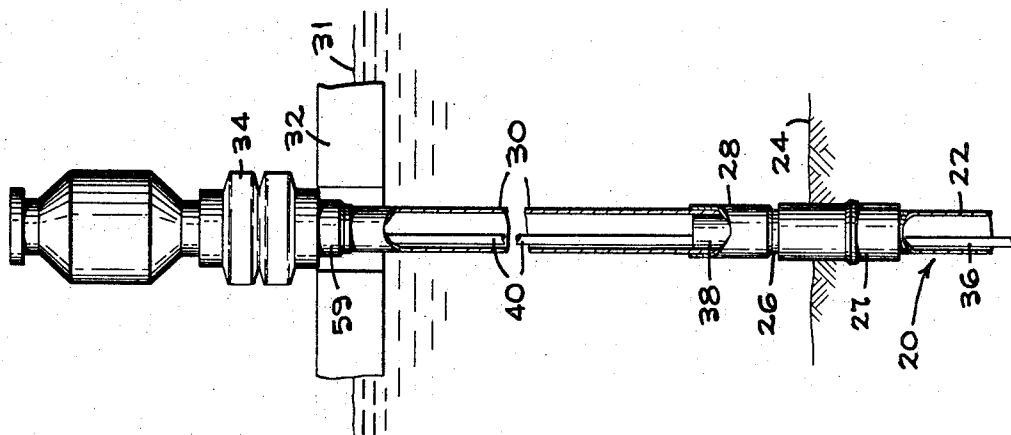
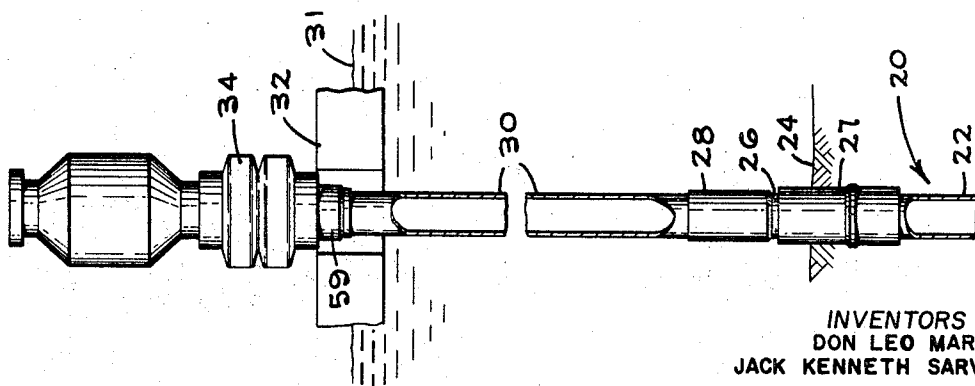


FIG. 1



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FIG 6

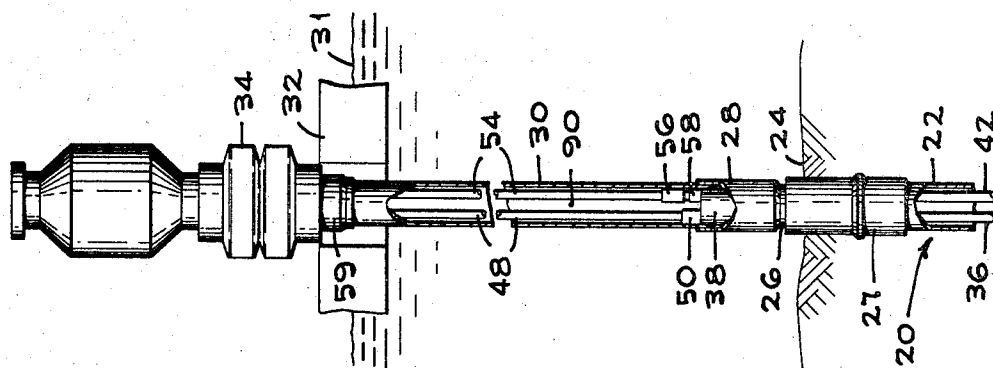


FIG 5

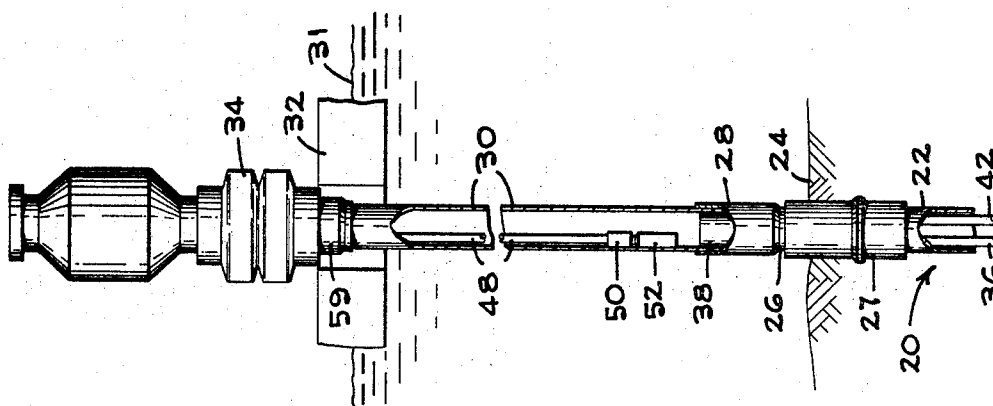


FIG 4

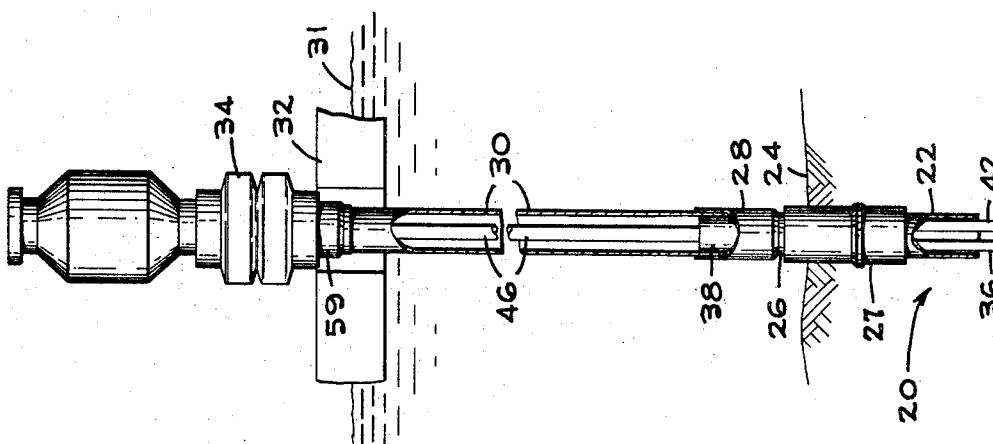


FIG 7

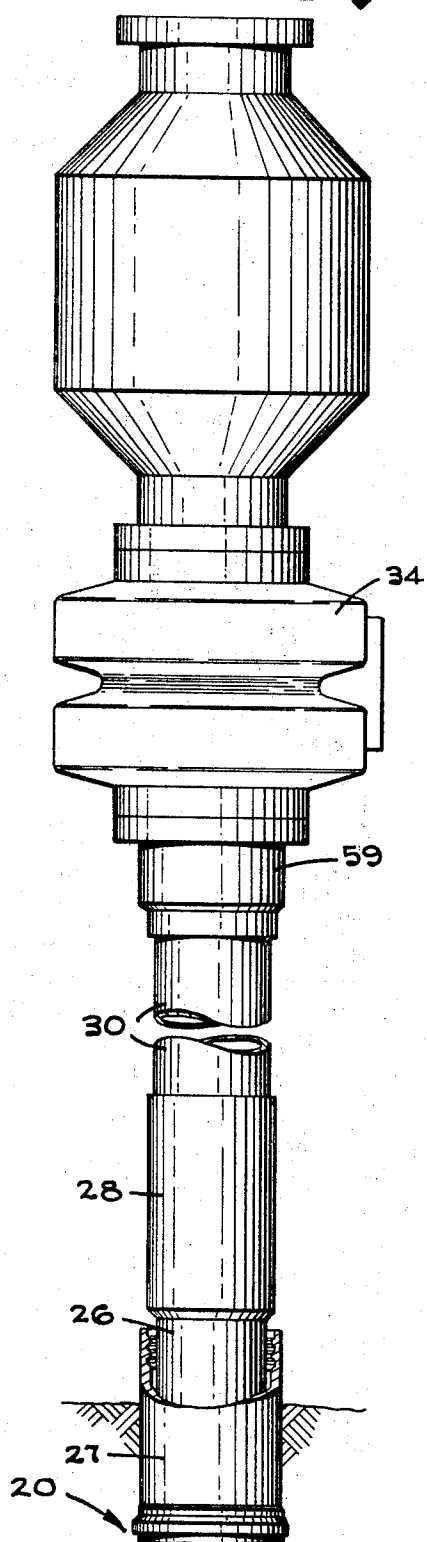
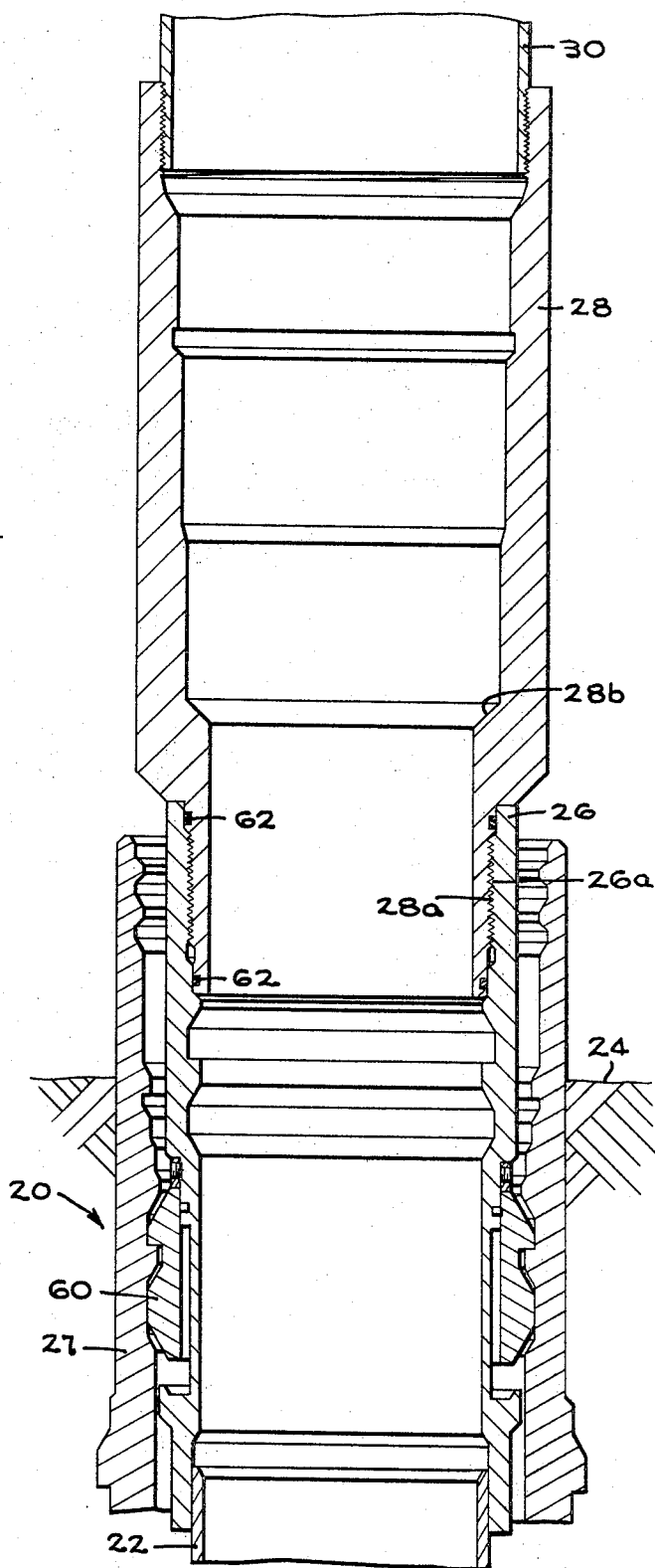
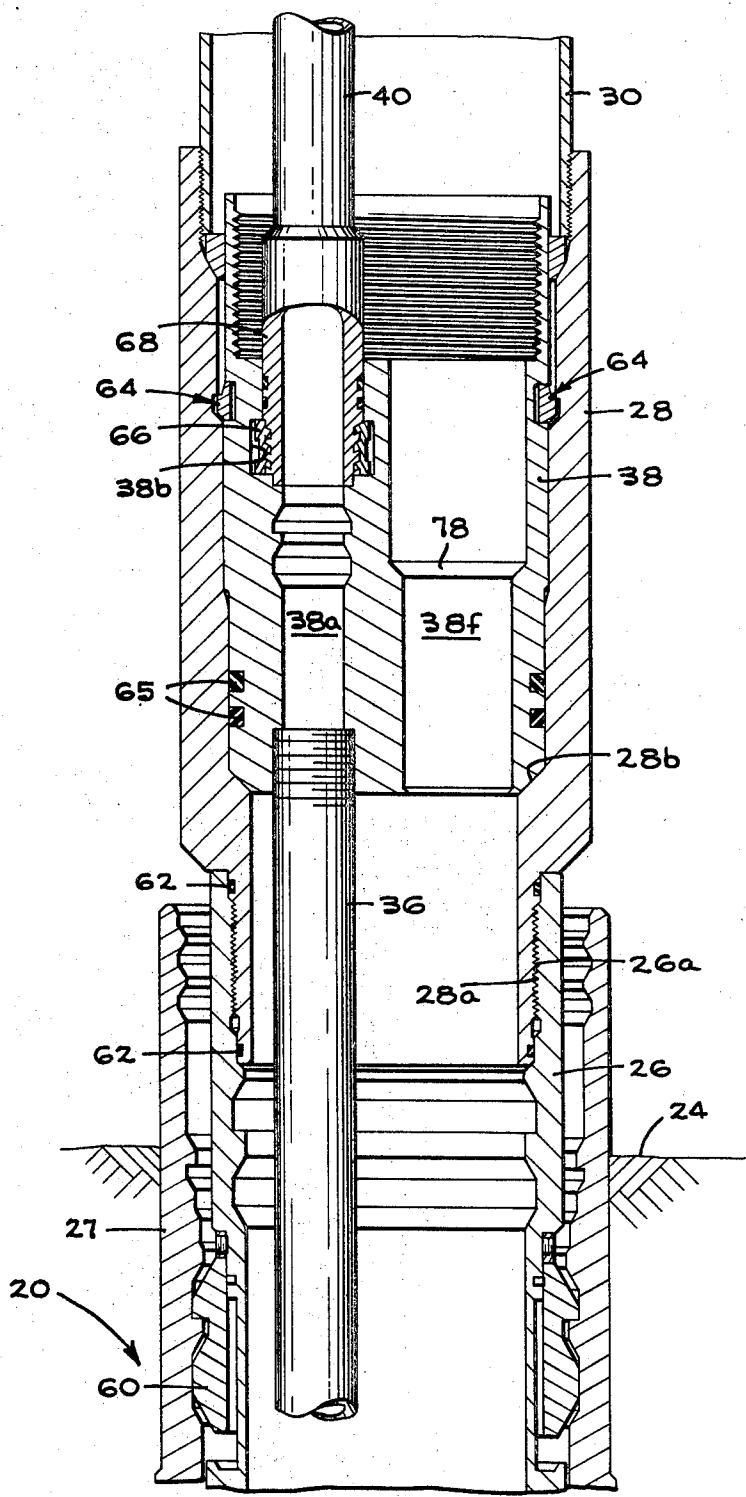


FIG 8





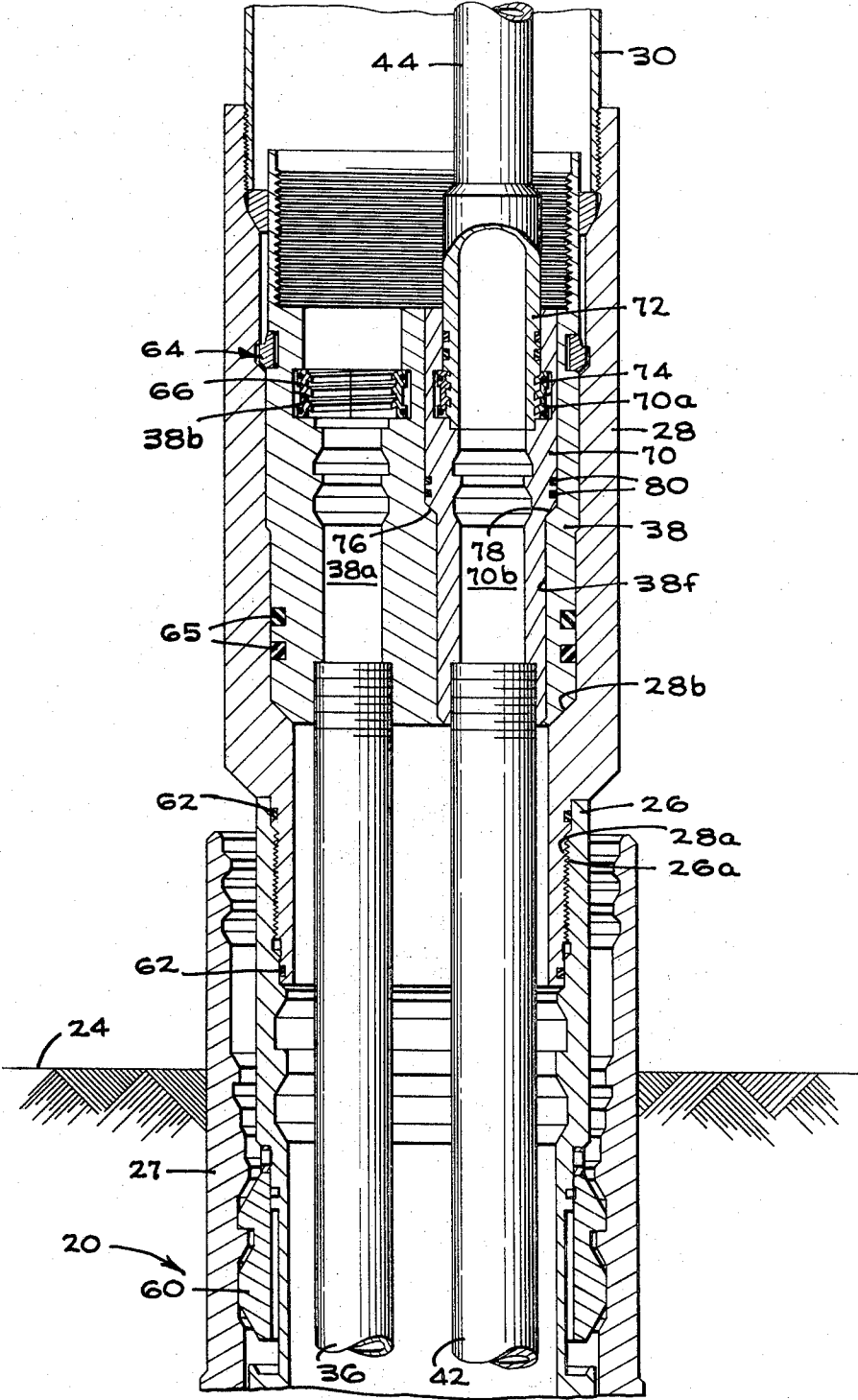


FIG. 10

FIG 12A

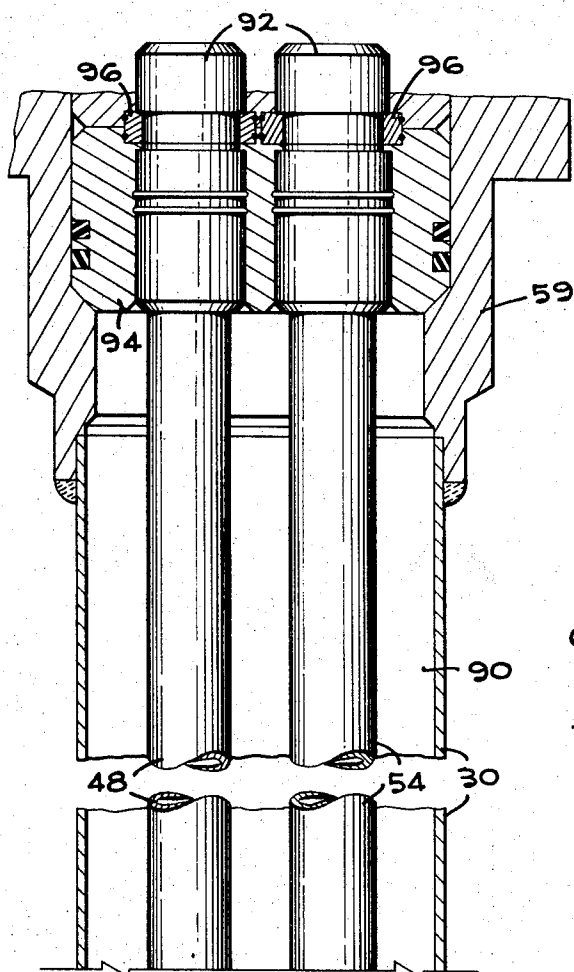
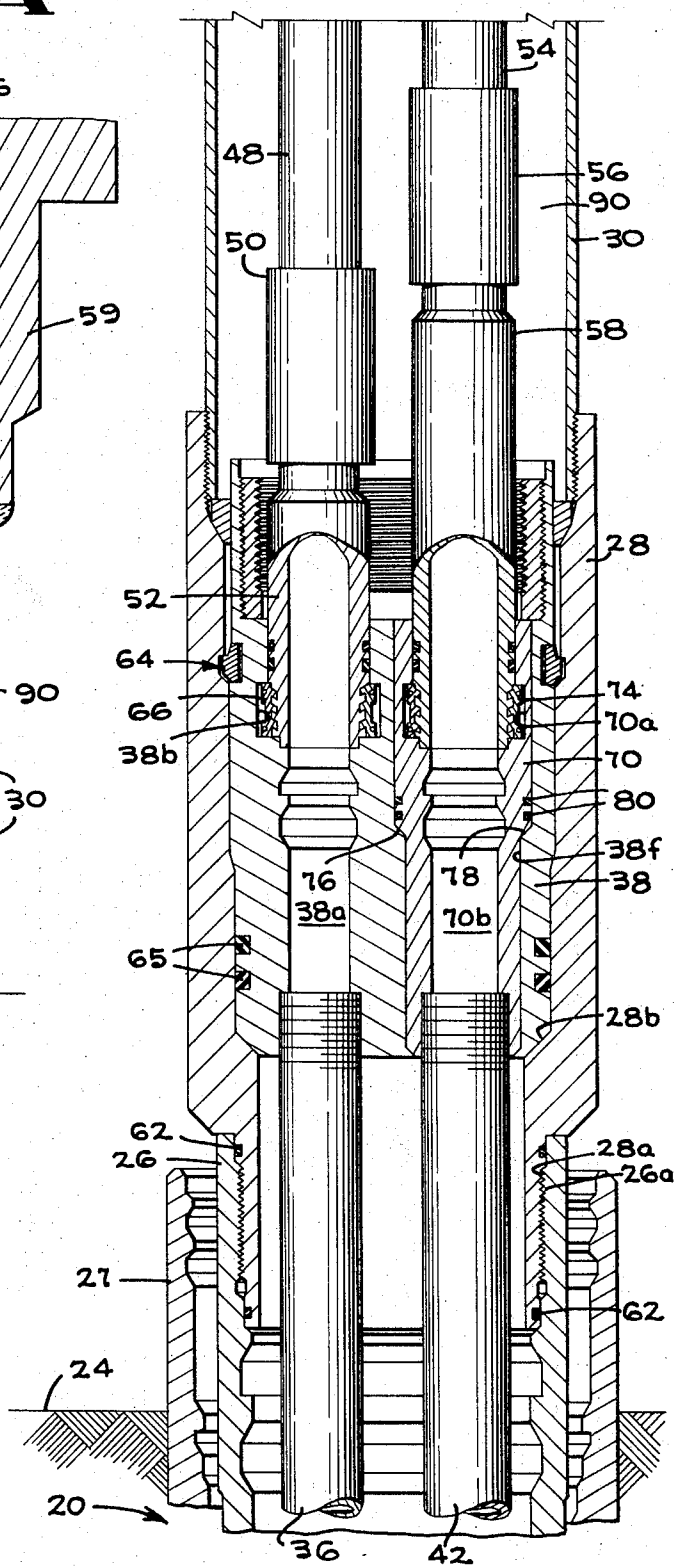


FIG 12B



OCEAN BOTTOM WELL TUBING VALVE INSTALLATION

BACKGROUND OF THE INVENTION

This invention relates to techniques for installing well tools in an off-shore, underwater oil or gas well, and to equipment used in performing those techniques. More specifically, this invention involves a method for installing remotely controllable valves in the tubing string system at the ocean floor or mudline in an offshore well, with the facility for removing the valves for servicing or replacement without withdrawing the tubing strings from the well. The field of art to which this invention pertains includes Class 166, subclasses .5, .6, 72, 241, 313, 314, and 315 of the classification of United States Patents.

The great and often irreparable harm to the environment, the great danger of loss of life, and the potentially great economic loss in terms of escaping petroleum or natural gas that can and have occurred when an off-shore oil or gas well is damaged by storms, surface vessels, etc. have given great impetus to the development of safety equipment for use in preventing such occurrences. Various types of devices for automatically closing in the well when damage occurs to the wellhead structure have been used for some time, and more recent developments have been directed toward incorporating remotely controllable valves in the production tubing strings at a subsurface level, such as at the ocean floor or mudline. These valves are designed to remain open when subjected to fluid under predetermined pressure, and to automatically close when this fluid pressure drops below a certain point, such as when the surface structure is damaged or carried away by a storm, ship collision, etc.

Although the principle behind these valves and their operation is sound, they all are plagued with disadvantages that reduce their efficiency. For example, some prior art mudline valve installations employ valve systems with flow passages materially less than the size of the bore in the tubing strings, and thus the volume of fluid that can be carried through the installation is significantly reduced. Another problem with some installations is that they require taking the well out of production for an undesirably long period of time in order to service or replace the valves. The usual servicing procedures involve either pulling all the tubing strings from the well, or using a wire line technique, both of which are expensive in terms of time and equipment. Yet another disadvantage with some of the more common installations is that an oil string at least two sizes larger than necessary to accommodate just the tubing strings must be used in order to also accommodate the valves, thereby requiring the other casing strings to be larger and resulting in much more expense.

SUMMARY OF THE INVENTION

Broadly considered, the present invention overcomes the foregoing disadvantages of the previous completion systems by providing a method for installing tubing string control valves at the ocean floor in such a way that they can be removed for servicing and replacement in a quick, efficient and easy manner, utilizing equipment of minimal size and complexity, and without necessitating removal of the well's tubing strings. As carried out on a well that has been drilled and lined with normal size casing that is suspended from a hanger

system at the ocean floor in the usual manner, the method of this invention comprises running and setting a riser pipe, of a diameter large enough to accommodate the valves, in the innermost casing hanger at the mudline so that the upper end of the riser is above the water's surface, installing a tubing head and blow-out preventer system at the surface platform or production deck level, running the tubing strings into the well and suspending them from equipment positioned at the ocean floor, and then running tubing extensions with the control valves positioned near their lower ends into the riser and connecting these extensions to the tubing strings. Depending upon the particular type of equipment that is used, the tubing extensions can be hung in the usual manner or they can be hung in tension. The method provides for release of the tubing extensions, together with their included control valves, and their subsequent removal from the well, as for servicing or replacement of the valves, without disturbing the tubing strings below. With this method, the well can be maintained in complete control during such servicing by installing back pressure valves in the tubing strings prior to removal of the tubing extensions.

The preferred apparatus employed in carrying out the foregoing method includes a tie-back adapter that threads into the upper end of the inner casing hanger, a master bushing that supports the tubing strings in the tie-back adapter and that is provided with annular packing elements and a locking mechanism to lock down and pack off the bushing into the adapter, and tie-back mechanisms for releasably securing the tubing extensions into the master bushing so that the extensions and the control valves can be easily released from the bushing and withdrawn from the well without necessitating removal of the tubing strings or the master bushing.

Accordingly, one object of the present invention is to provide a new method for installing a tubing string flow control valve in an oil or gas well at a subsurface location remote from the wellhead.

Another object of the present invention is to provide a method for releasably installing tubing control valves in the production tubing conduit system of an off-shore well at the ocean floor or other remote location below the level of potential damage to the well by storms or ship collisions.

Yet another object of the present invention is to provide a method for removing remotely controllable tubing valves from a subsurface location in an off-shore well for servicing or replacement, without also having to remove the tubing strings from the well.

Yet another object of the present invention is to provide a method for installing subsurface tubing control valves with equipment of standard size, thereby facilitating substantial reductions in costs incurred with other methods already known.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1-6 schematically illustrate the sequential steps of completing an underwater well with dual tubing strings according to the present invention.

FIG. 7 is a schematic view, on an enlarged scale, of equipment that can be employed to complete a well according to the invention, including the surface located wellhead and blow-out preventers, the tie-back adapter at the ocean floor or mudline, and the riser between the tie-back adapter and the surface.

FIG. 8 is a longitudinal view in cross section, on an enlarged scale, of the lower portion of the apparatus of FIG. 7 showing the lower end of the riser, the tie-back adapter to which it is connected, and the innermost casing hanger in which the tie-back adapter is set.

FIG. 9 is a view like FIG. 8, showing the state of completion after the master bushing and first tubing string have been run and set in the tie-back adapter, and prior to release of the running string from the master bushing.

FIG. 10 is a view like FIG. 9, showing the state of completion after running and setting the second tubing string and its coupling into the master bushing, and prior to removal of the running string from the upper end of the coupling.

FIG. 11 is a view like FIGS. 9 and 10, showing the state of completion after the second tubing string has been locked in place in the master bushing by the tie-down ring, and just prior to removal of the tie-down ring running string.

FIGS. 12A and 12B together illustrate the condition of the well following completion by the method of the present invention, showing the tubing extensions hung in tension between the master bushing and the tubing head, and the remotely controllable downhole valves in position in the tubing extensions at the mudline.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Considering the method of the present invention from a broad point of view, attention is directed to FIGS. 1-6 of the drawings which show, in sequence, the several steps involved when this method is followed in effecting a dual completion in an offshore well 20 that has an inner casing 22 supported at the ocean floor or mudline 24 by a hanger 26, which in turn is supported in an outer casing hanger 27. The first step involves running and connecting a tie-back adapter 28 with a riser 30 into the hanger 26. The riser 30, which extends from the tie-back adapter 28 to the water surface 31, is then cut off at the level of the platform production deck 32, and a blow-out preventer system 34 installed. At this point, the tie-back seals, the riser and the blow-out preventer stack can be tested in the usual manner with a cup (not shown) run on drill pipe into the casing 22 below the hanger 26.

As illustrated in FIG. 2, a first or long tubing string 36 and a master bushing 38 to which it is connected are then run by means of a tie-back string 40, and the master bushing locked in place in the tie-back adapter 28. The master bushing 38 is connected to the tie-back string 40 so that the string can be released from the bushing by rotating the string to the right. Accordingly, once the master bushing 38 has been set in the tie-back adapter 28, right-hand rotation is imparted to the tie-back string 40 until it is released from the master bushing, and the string is then withdrawn.

As shown in FIG. 3, a second tubing string 42 is then run and landed in the master bushing 38 by means of a tie-back string 44. Like the connection between the string 40 and the master bushing 38, the string 44 is connected to the second tubing string 42 in such a manner that right-hand rotation will disconnect it. Thus, following the landing of the second tubing string 42 in the master bushing 38, the tie-back string 44 is rotated to the right, releasing it from the string 42, and then withdrawn.

FIG. 4 illustrates the next step in this method, that of locking down the second tubing string 42 into the master bushing 38. This step can be accomplished by running a tie-down ring (FIG. 11) on the end of a string of drill pipe 46 into the master bushing and securing it thereto. The running string 46 is then released from the tie-down ring and withdrawn.

With both tubing strings 36,42 now effectively locked into the tie-back adapter 28, each string is then completed to the surface by a tubing extension containing a remotely controllable, full opening valve adjacent its lower end. As illustrated in FIG. 5, the first tubing string 36 is continued to the surface by running a tubing extension 48, containing a flow control valve 50, and releasably interconnecting the extension and the tubing string through the bushing 38, as by means of a tie-back mechanism 52. Next, and as illustrated in FIG. 6, the second tubing string 42 is completed to the surface by releasably connecting a tubing extension 54, having a flow control valve 56, to it by a tie-back mechanism 58. If it is desired to suspend the tubing extensions 48,54 in tension, the blow-out preventer stack 34 can then be picked up off the tubing head 59, tension applied to the extensions, and split tension rings or the like installed. A tree can then be mounted at the surface in the conventional manner.

Thus, following the foregoing method, the well 20 can be completed with dual tubing strings 36,42 each of which is locked down and supported at the mudline 24, and releasable tubing string extensions 48,54 from the mudline to the surface located wellhead. Since the flow control valves 50,56 are in the tubing string extensions 48,54 rather than in the master bushing 38 or the tubing strings 36,42 these valves can be removed from the well for servicing or replacement simply by releasing and pulling the tubing string extensions, leaving the tubing strings secured in place in the bushing at the ocean floor. In order to maintain the well 20 in control while the valves 50,56 are removed, conventional back pressure valves (not shown) are run through the tubing string extensions 48,54 and the valves 50,56 into the master bushing 38 and secured thereto, and when the tubing string extensions are reinstalled these flow control valves are removed. Furthermore, because of the unique placement of the valves, there is no problem in completing a well that has been drilled and lined with standard size casing.

Accordingly, the foregoing method results in a well completion that provides full opening valves for controlling the flow in each tubing string on or near the ocean bottom, and facilitates quick and easy removal of these valves for servicing or replacement without having to remove the tubing strings or otherwise relinquish control over the well. This means that a considerable savings in time and expense can be realized as compared with when it is completed by other techniques, and it also provides the highly desirable safety feature of automatic closure of the well's tubing strings at the ocean floor in the event of damage to or malfunction of the well structure above that level.

The foregoing method is entirely compatible for use with ball or other various types of remotely controllable valves currently available in the industry for use in tubing strings. Surface control of these valves can be achieved by maintaining hydraulic fluid under pressure in the annulus 90 between the tubing extensions 48,54 and the riser 30, or by running hydraulic lines from the

surface through this annulus down to the valves. In either case, should the pressure of the fluid drop below a predetermined level, such as if the surface equipment is damaged by a storm, ship, etc., the valves will automatically close and will remain closed until sufficient pressure in the fluid control system is reestablished.

Although it should be understood that apparatus of various types can be used to carry out the foregoing described well completion method, a preferred apparatus which has been found highly successful in this regard is illustrated in detail in FIGS. 8-12. In these Figures the apparatus is shown in conjunction with a well that has been lined with casing that is suspended from a location at or near the ocean floor or mudline 24, and with the innermost casing string 22 (FIG. 8) secured to a casing hanger 26. The hanger 26 is of the type described in U.S. Pat. No. 3,420,308 to Samuel W. Putch, having a resiliently expandible and contractable hanger ring 60 that releasably secures the hanger 26 to an outer casing hanger 27. The tie-back adapter 28 is provided at its lower end with external right hand threads 28a that mesh with internal right hand threads 26a at the upper end of the casing hanger 26, so that the tie-back adapter and the riser 30 to which it is threaded can be run and connected into the hanger 26 by rotation of the riser to the right. Annular seals 63 are provided between the tie-back adapter 28 and the hanger 26 in the conventional manner, and the blow-out preventer stack 34 together with the tubing head 59 are mounted on top of the riser 30 at the level of the surface production platform 32.

An annular shoulder 28b in the lower portion of the tie-back adapter 28 provides a landing and support surface for the master bushing 38, and a releasable locking system 64, such as outwardly biased locking dogs, functions to releasably secure the bushing into the tie-back adapter. Annular packings at 65 provide a fluid tight barrier between the bushing 38 and the adapter 28.

The first tubing string 36 is threaded into the lower end of the master bushing 38, in alignment with the bushing's bore 38a that continues the flow passage from the tubing string 36. Near the upper end of the bore 38a is an annular groove 38b that serves as the housing for an inwardly biased segmented nut 66 that constitutes the female portion of a tie-back system for releasably connecting the tie-back string 40 to the master bushing 38. The male portion of this tie-back system comprises an adapter 68 attached to the lower end of the tie-back string 40. The lower outside diameter of the adapter 68 is provided with special left-hand buttress-type threads which have a negative rake angle, to lock the adapter to the segmented nut 66 when the adapter is stabbed into it. Thus, the connection between the tubing extension 40 and the master bushing 38 is achieved simply by stabbing the adapter 68 into the position shown in FIG. 9, and release of the string 40 is achieved simply by rotating it to the right while simultaneously lifting on it.

As shown in FIG. 10, the second tubing string 42 is threaded into the bottom of a tubing coupling 70, and the tie-back string 44 is releasably connected to the upper end of the coupling 70 by the same type of tie-back mechanism as that between the string 40 and the master bushing 38. This mechanism includes an adapter 72 on the lower end of the string 44, and a segmented nut 74 in an annular groove 70a in the tubing coupling's bore 70b. In the conventional manner, the

tubing coupling 70 has an annular shoulder 76 that lands on an annular shoulder 78 in the bore 38f of the master bushing 38, and the coupling is sealed to the bushing by an annular seal system 80. Thus, once the second tubing string 42 has been run and set in the master bushing 38 by the tie-back string 44, the string 44 can be released by simultaneous right-hand rotation and lifting, and then withdrawn.

In order to lock down the second tubing string 42 into the master bushing 38, a lock down ring 82 (FIG. 11) is run by means of a tool 84 on the running string 46, and threaded into the upper end of the master bushing 38 until it comes to rest against the upper end of the tubing coupling 70. The running tool 84 is connected to the lock down ring 82 by left hand threads 84a, so that once the ring is set in the master bushing 38 continued right hand rotation of the running string 46 and tool 84 will unthread the tool from the ring, thereby facilitating its withdrawal. It will be seen, therefore, that at this stage of the method both tubing strings 36,42 are secured in a fluid tight manner to the master bushing and the bushing is locked down and packed off into the tie-back adapter 28. Thus, the well is now ready for completion to the surface.

Completing the tubing string 36,42 to the surface with the illustrated equipment is accomplished by running and setting a tubing extension 48 (FIGS. 12A and 12B) into the master bushing 38, and another tubing extension 54 into the tubing coupling 70. As shown in FIG. 12B, the lower end of the tubing extensions 48,54 terminate in male tie-back adapters 52,58 respectively, that stab into the segmented nuts 66,74 respectively, of the tie-back mechanisms. Likewise, the tubing extensions 48,54 can be released from their connections to the bushing 38 and coupling 70 by lifting on them while also rotating them to the right.

A flow control valve 50 is positioned just above the male adapter 52 in the tubing extension 48, and another flow control valve 56 is positioned in the tubing extension 54 just above the level of the adapter 58. Valves suitable for use at these locations are well known in the industry, and since their details form no part of the present invention they will not be described. Suffice it to say that these valves are maintained in an open position by fluid pressure which can exist either in the annular space 90 between the riser 30 and the tubing extensions 48,54 or by fluid under pressure carried to the valves by means of conventional hydraulic lines (not shown). When this fluid pressure is below that preestablished to maintain the valves in the open condition, the valves will automatically close and will remain closed until the requisite amount of pressure is reestablished.

The upper ends of the tubing extensions 48,54 can be supported by any of several conventional and well known means, including the tubing head 59 and related equipment such as that illustrated in FIG. 12A. In this illustrated arrangement, the upper ends of the tubing extensions 48,54 are secured to tension hanger couplings 92 that are held in place in a tension hanger bushing 94 by split tension rings 96.

Although the foregoing description explains the invention in terms of withdrawing both tubing valves from the well for servicing or replacement, it should, of course, be understood that either one of the valves may be withdrawn alone, leaving the other valve in place, and then reinstalled (or a new valve installed in its

place) as might be desired. In other words, an additional and highly advantageous feature of this invention is that it permits the operator to service or replace just one of the tubing valves, rather than having to withdraw both valves as is required when other completion methods are followed. This feature affords a savings, both in time and equipment, and makes the inventive method considerably more versatile.

Still another advantage associated with the use of the present invention is that it can be carried out fully from the surface, i.e., no assistance from divers at the ocean floor is required. This is especially important where the well has been drilled at an offshore location too deep for diver access, as is becoming more frequently the case. Consequently, where such a deep location is encountered, the several advantages discussed above are available only if the method of this invention is followed in bringing the well to completed condition.

Although the best mode contemplated for carrying out the present invention has been herein shown and described, it will be apparent that modification and variation may be made without departing from what is regarded to be the subject matter of the invention.

What is claimed is:

1. A method for remote completion of an underwater well for production of fluids therefrom, the well having at least one string of casing, comprising the following steps:

- a. running and connecting a riser to the casing to provide a continuous conduit from the casing to the surface;
- b. running at least one tubing string through the riser and landing said string in the well approximate the location of the lower end of the riser;
- c. running a tubing extension equipped with a tubing flow control valve into and down the riser to the landed tubing string; and
- d. releasably connecting the tubing extension into fluid-tight flow communication with the landed tubing string,

whereby the tubing flow control valve can be withdrawn from the well for servicing or replacement without having to remove or otherwise disturb the tubing string from its landed position in the well.

2. A method according to claim 1 including the step of locking down and packing off the tubing string to establish a fluid-tight seal between it and the casing.

3. A method according to claim 1 wherein two tubing strings are run through the riser, and wherein two tubing extensions, each including a tubing flow control valve, are run into and down the riser and releasably connected to the two landed tubing strings, one extension per string.

4. A method according to claim 3 wherein the first tubing string is connected at its upper end to a master bushing that is run, landed and locked down with said first tubing string, and wherein the second tubing string includes a tubing coupling that is run, landed and locked down into said master bushing.

5. A method according to claim 3 wherein the tubing extensions are releasably secured at their upper ends to a surface located tubing support means connected to the riser.

6. A method according to claim 5 wherein the tubing extensions are hung in tension from the tubing support means.

7. A method for remote completion of an underwater well for production of fluids therefrom, the well having at least one string of casing, comprising:

- a. running and connecting a riser to the casing to provide a continuous conduit from the casing to the surface;
- b. running a first tubing string and a master bushing, connected to the upper end of said tubing string, through the riser, and landing and locking down said first tubing string and said master bushing in the well approximate the location of the lower end of the riser;
- c. running a second tubing string that includes a tubing coupling through the riser, and landing said tubing coupling in the master bushing;
- d. locking down the second tubing string into the master bushing by running and connecting a locking means to said master bushing;
- e. running two tubing extensions, each including a tubing flow control valve, into and down the riser; and
- f. releasably connecting the two tubing extensions to the two tubing strings, one extension per string, whereby the tubing flow control valves can be withdrawn from the well for servicing or replacement without also removing or otherwise disturbing the tubing strings from their landed condition in the well.

8. A method for remote completion of an underwater well for production of fluids therefrom, the well having at least one string of casing, comprising:

- a. running and connecting a riser to the casing to provide a continuous conduit from the casing to the surface;
- b. running first and second tubing strings through the riser and landing said strings in the well approximate the location of the lower end of the riser;
- c. running a tubing string lock down means through the riser, and landing said tubing string lock down means to releasably secure said second tubing string in the well;
- d. running two tubing extensions, each including a tubing flow control valve, into and down the riser; and
- e. releasably connecting the tubing extensions to the two tubing strings, one extension per string, whereby the tubing flow control valves can be withdrawn from the well for servicing or replacement without also removing or otherwise disturbing the tubing strings from their landed condition in the well.

9. A method for completing an offshore underwater well from a remote, water surface location, said well containing at least one string of casing extending downward from the ocean floor, comprising:

- a. running a riser, having a connector means at its lower end, to the well and connecting said riser to the casing;
- b. running a first tubing string, connected at its upper end to a master bushing, into the well, and landing and locking said master bushing in said connector means;
- c. running a second tubing string, connected at its upper end to a tubing coupling, through the riser and the master bushing and landing said tubing coupling in said master bushing;
- d. running a lock down means to the master bushing and locking down the second tubing string and the tubing coupling;

e. running a first tubing extension, including a tubing flow control valve, through the riser and releasably securing said tubing extension to the master bushing in flow communication with the first tubing string; and

f. running a second tubing extension, including a tubing flow control valve, through the riser and releasably securing said second tubing extension to the tubing coupling in flow communication with the second tubing string,

whereby said tubing flow control valves can be individually disconnected from said tubing strings and removed from the well for servicing or replacement while said tubing strings remain undisturbed in the well.

10. A method according to claim 9 including suspending the tubing extensions from a tubing head

mounted on the riser at a surface location.

11. A method according to claim 10 wherein the tubing extensions are suspended in tension from the surface located tubing head.

5 12. A method according to claim 9 including automatically locking down and packing off the master bushing into the connector means adapter.

13. A method according to claim 9 wherein the connector means comprises a tie-back adapter that is run 10 with the riser and connected into the casing in fluid-tight relationship therewith.

14. A method according to claim 9 wherein the lock down means comprises a lock down ring that is threaded to the master bushing to lock the second tubing string into said bushing. 15

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,770,053
DATED : November 6, 1973
INVENTOR(S) : DON LEO MARTIN ET AL

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 10, line 7 - delete "adapter".

Signed and sealed this 27th day of May 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks