

[54] WELL REENTRY SYSTEM

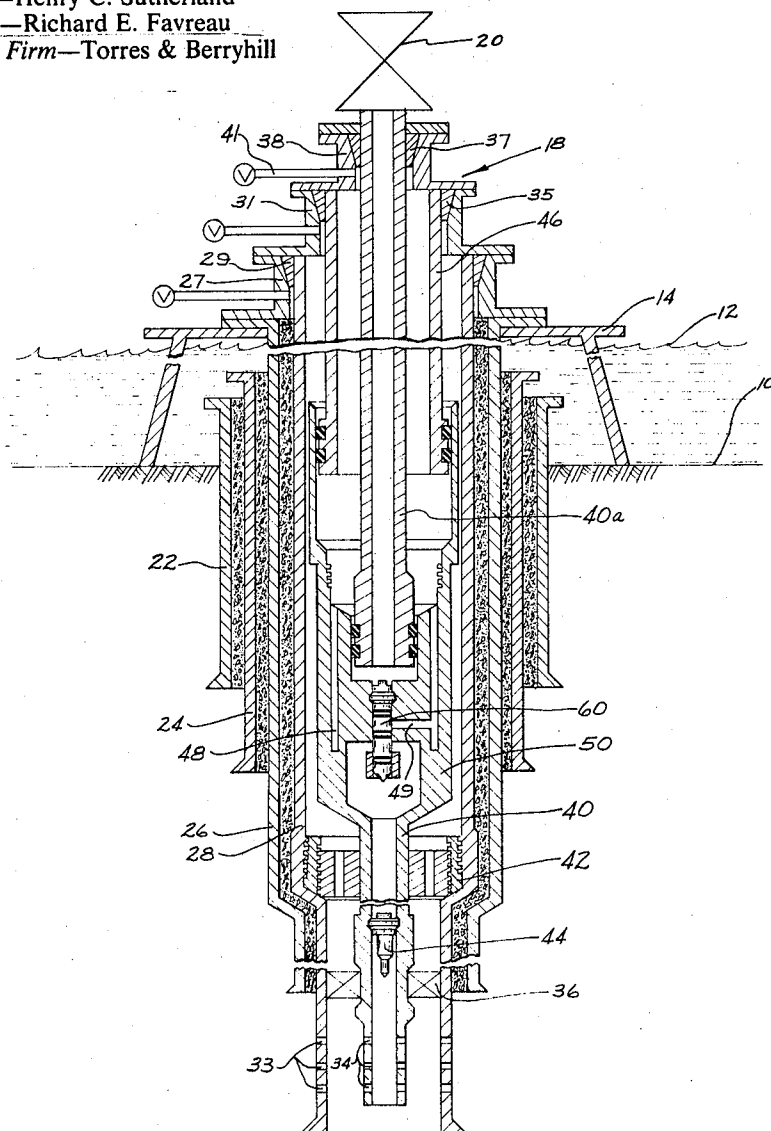
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2,607,422	8/1952	Parks et al.	166/5
3,137,348	6/1964	Ahlstone et al.	166/6
3,196,958	7/1965	Travers et al.	166/5 X
3,516,492	6/1970	Petersen	166/6
R26,149	1/1967	Sizer et al.	166/224 X
R27,464	8/1972	Taylor	166/5

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[57] **ABSTRACT**

Method and apparatus for completing a well having a wellhead supported on a platform above a body of water and the well bore of which penetrates the floor of the body of water. The method comprises the steps of: running at least one casing string into the well bore; cementing the casing string in the well bore; running a first portion of a tubing string into the casing string; suspending the first portion of the tubing string in the casing string at a point below the floor; lowering a second portion of the tubing string through the body of water into sliding and sealing telescopic engagement with the upper end of the first portion of the tubing string; and suspending the second portion of the tubing string at the wellhead. The apparatus may comprise a safety valve assembly installed in the first portion of the tubing string at a point below the water body floor. The valve assembly may be hydraulically operated by fluid conducted to the valve assembly through a conduit supported at the wellhead and extending through the body of water for fluid-tight communication with the valve assembly.

16 Claims, 4 Drawing Figures

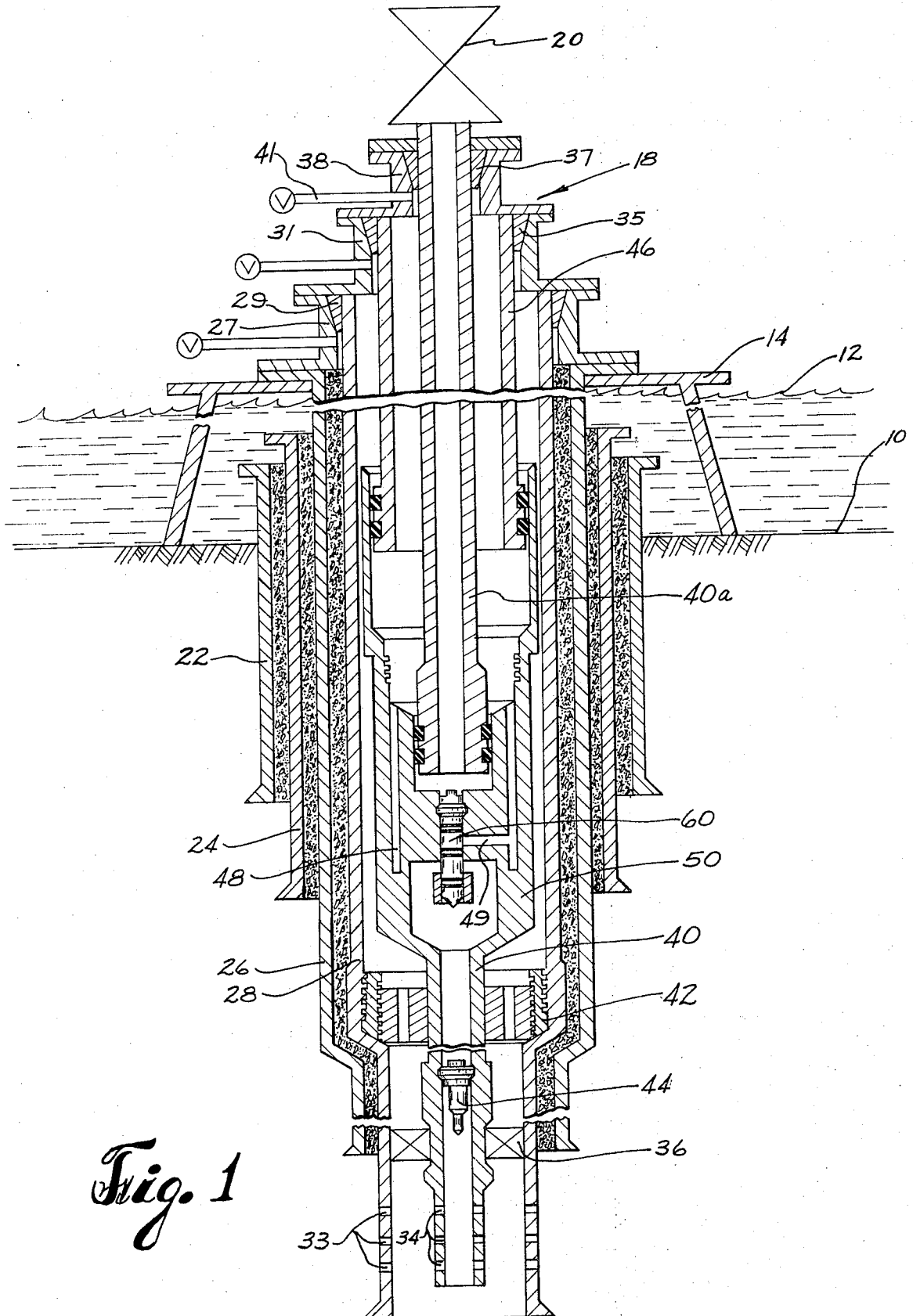
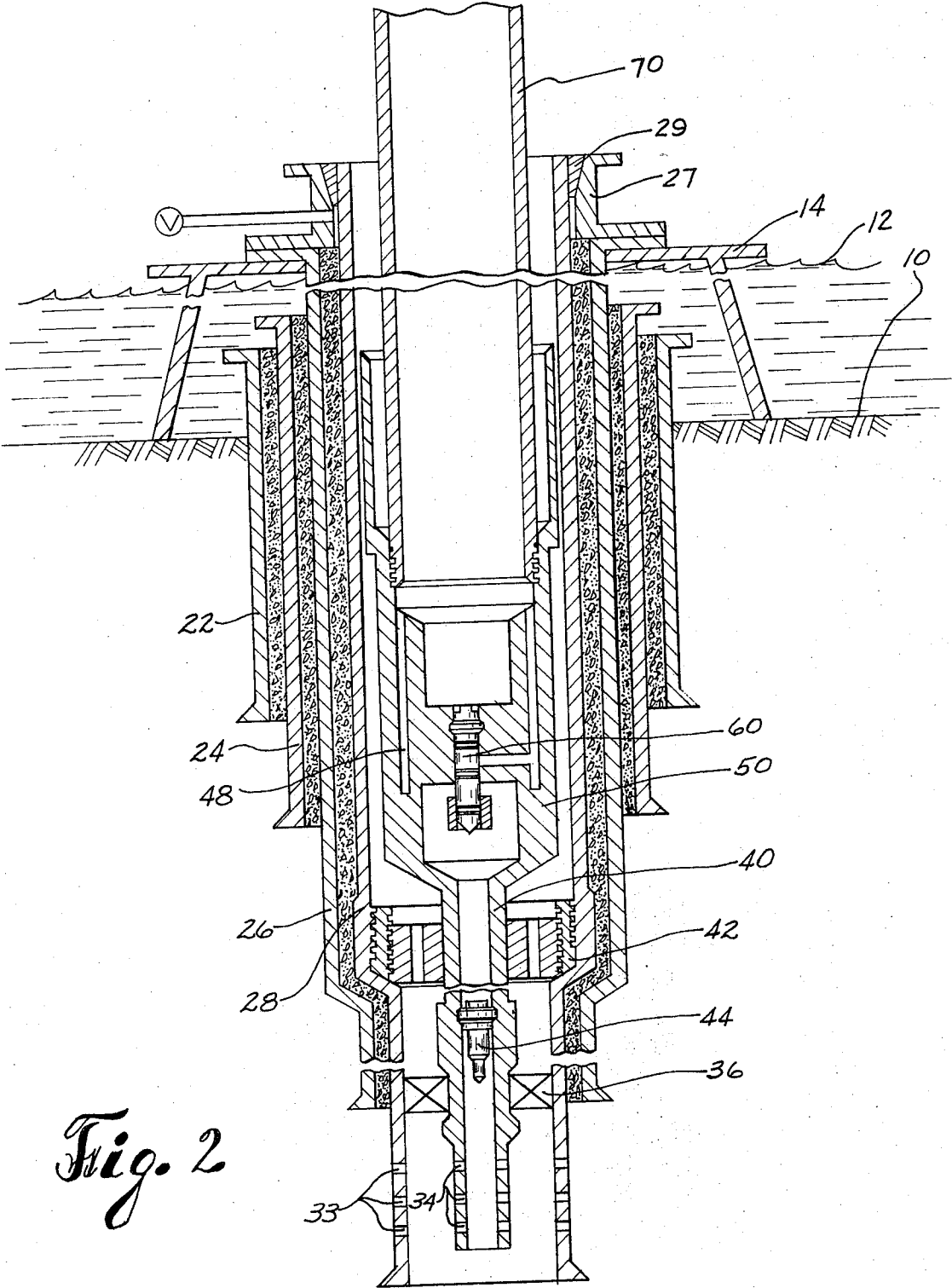


Fig. 1



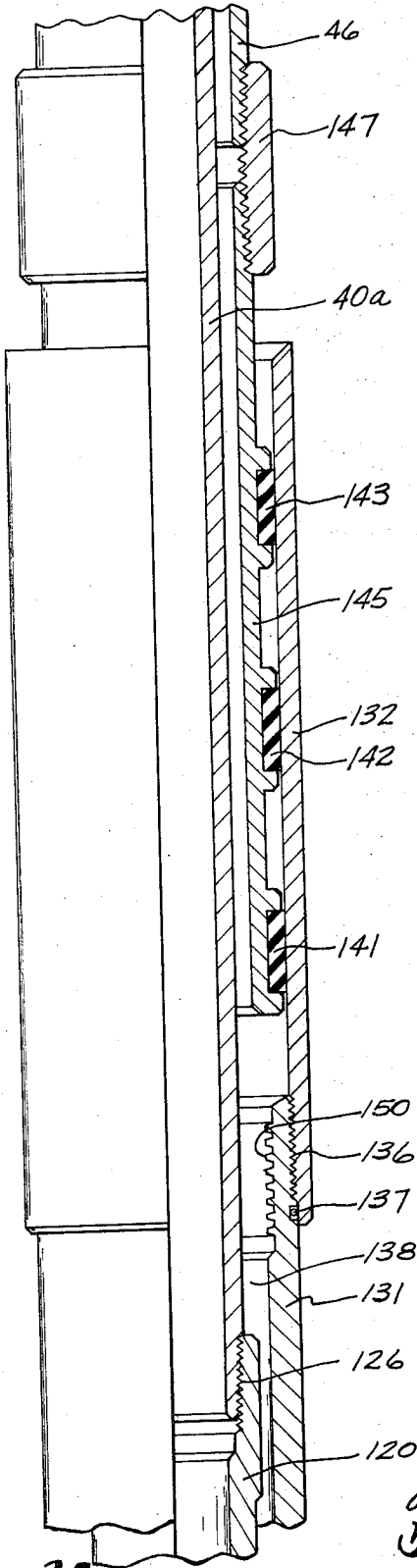


Fig. 3A

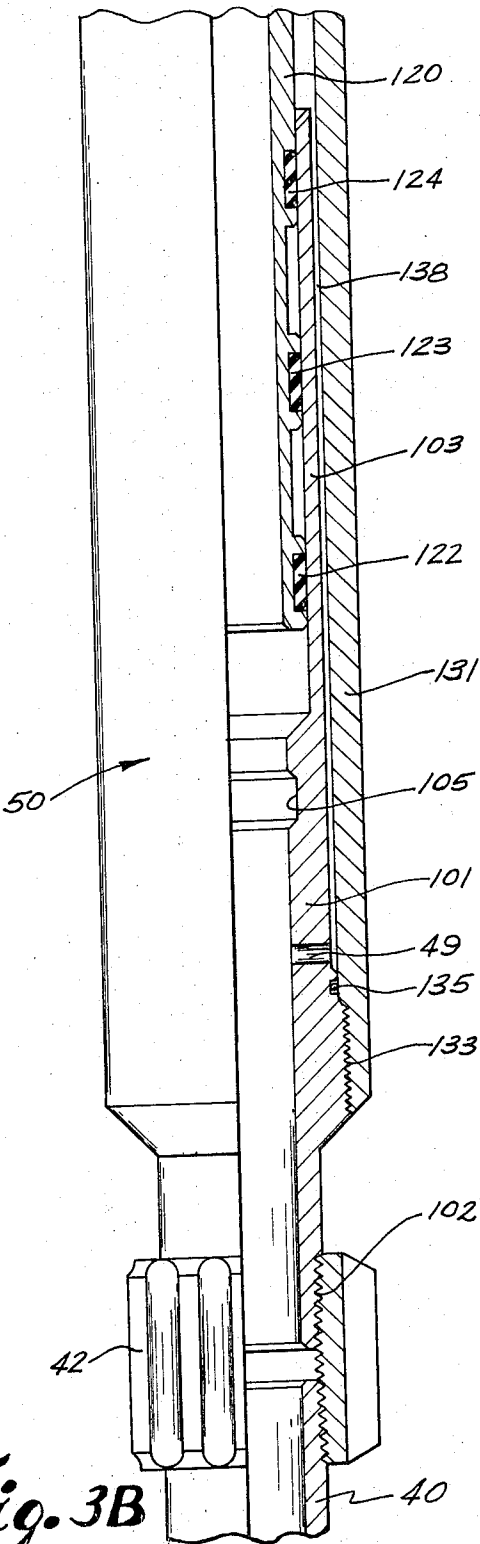


Fig. 3B

WELL REENTRY SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention pertains to methods and apparatus for completing wells for production of petroleum deposits. More specifically, it pertains to completion of wells whose producing formations lie below a body of water. More particularly, it concerns methods and apparatus for completing an underwater well, in which the well may be safely shut in and reentered for plugging or recompletion in the case of damage to the well platform or other components of the well supported thereby.

2. Description of the Prior Art

For the last few years, there has been an ever increasing ecological concern for man's environment. There has probably been more publicity about this concern in connection with offshore oil wells than in any other specific area.

Offshore oil wells, of course, are a potential source of the water pollution. Much has been done in the past few years to reduce the possibilities for the occurrence of accidents which would cause pollution by these wells. Industry concern and government regulations have been responsible for the development of down-hole safety valves and other equipment for closing off damaged wells.

Although much has been done to eliminate dangerous explosions and pollution resulting from damaged wells, further improvements are needed. For example, even though a way of shutting in a well whose platform has been damaged may have been devised, it is extremely difficult, expensive and sometimes impossible to properly recomplete the well or even to plug it. This is primarily due to the fact that when a well platform is damaged, the casing and tubing string supported thereby are also frequently damaged. This may require cutting the pipe and reattaching some substitute apparatus. Such operations on underwater wells are extremely difficult, expensive, and hazardous.

SUMMARY OF THE INVENTION

In the present invention, a method and apparatus for completing an underwater well is disclosed in which the portion of the tubing string below the floor of the body of water is supported at a point below the floor while the remaining part of the tubing string extending upwardly to the platform is supported at the platform. A telescoping connector joint is provided whereby the platform supported portion is in fluidtight communication with the underwater supported portion. A safety valve is installed in the under floor supported portion of the tubing string and in fluid communication with the platform through a hydraulic conduit extending upwardly to the platform. The safety valve is adapted to close when it loses pressure, resulting from damage to the platform. The hydraulic conduit is also adapted for telescopic engagement with the portion of the tubing string supported below the floor of the water body and may comprise a pipe string surrounding the tubing string, leaving an annular space therebetween.

Upon damage to the platform, the upper portion of the tubing string and the hydraulic conduit, if they have not already done so, may be disconnected from the un-

derfloor supported portion of the tubing string by simply pulling upwardly thereon. A special connection may be provided whereby a kill string may then be attached to the tubing string at a point near the water body floor so that fluid may be pumped therethrough to kill the well. The well may then be plugged or recompleted.

Since the portion of the tubing string below the water body floor is supported independently of the platform, there is no damage to the tubing string, thus making the killing of the well or recompletion possible. Furthermore, there is no danger of polluting the body of water. Other hazards are also eliminated. Other objects and advantages of the invention will be apparent to those skilled in the art from reading the description which follows in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the description which follows, reference will be made to the accompanying drawings in which:

FIG. 1 is a schematic representation of an underwater well showing apparatus supported by a platform and apparatus supported independently of the platform below the floor of a body of water;

FIG. 2 is a schematic representation of the underwater well of FIG. 1, showing the platform supported portions of the tubing string and hydraulic oil string removed and a kill string connected for killing the well;

FIG. 3A is an elevation view, in quarter-section, of exemplary apparatus for completing a well in accordance with the present invention; and

FIG. 3B is an elevation view, in quarter-section, of the exemplary apparatus of FIG. 3A and being a continuation of FIG. 3A.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring first to FIG. 1, there is shown a well the bore of which penetrates the floor 10 of a body of water 12. A platform 14 is provided on which is supported a wellhead 18 including a production manifold or Christmas tree 20. Initially, a conductor casing 22 is driven into the floor 10. The conductor 22 may alternately be placed in a hole drilled therefor. Another casing string 24, sometimes referred to as a surface casing, may be placed in a hole drilled therefor and cemented in place.

Next, a hole for an intermediate casing string 26 may be drilled and the intermediate string may be placed in the hole and cemented in place. The intermediate string may be a tapered one, that is, the upper portion may be of a larger diameter, for example, 13 $\frac{3}{4}$ inches, while the lower portion is of a smaller diameter, for example, 10 $\frac{3}{4}$ inches. The intermediate string may be extended upwardly to the platform 14 where a casing head 27 may be surmounted thereon. Another casing string 28, which may be referred as the production casing, is then placed in a hole drilled therefor and cemented therein. The production casing may also be a tapered string, for example, 10 $\frac{3}{4}$ inches $\times$ 7 $\frac{1}{2}$ inches. It also may extend upwardly to the platform 14 where it is packed off and hung by a set of slips 29 in casing head 27. Another casing head 31 may be surmounted on lower casing head 27 and production casing 28. So far, this method of completion does not substantially

differ from conventional underwater completion methods.

Finally, one or more tubing strings 40 is run into the well for conducting production fluids to a Christmas tree for further handling. The portion of the tubing string 40 below the floor 10 is supported by a flow-through hanger 42 which is in turn supported by the production casing string 28 at the point of reduction of the casing string from one size to another. Although it is not necessary that the production casing be tapered, this does provide a convenient location for supporting the hanger 42. If the production string were of the same size throughout, a special landing nipple could be provided to support the hanger 42. The production casing and tubing string are conventionally perforated, as shown at 33 and 34, respectively. A packer 36 is provided to isolate the production zone. A pressure bellows safety valve 44 may be installed in the tubing string. Such safety valves are known in the art and the purpose is to shut in the well in case flow through the tubing string exceeds a predetermined value.

Provided in the tubing string 40 at a point, normally just below the floor 10 of the body of water, is a tubing flow connector 50, to be more fully described hereafter. Sealingly engaging the connector 50 in a telescopic fit is the upper portion 40a of tubing string 40. The upper portion extends upwardly to the platform 14 where it is supported by slips 37 in a tubing head 38 surmounted on casing head 31. Also engaging the connector 50 is a sealing telescopic fit may be a hydraulic oil string 46 which extends upwardly to the platform 14 where it is supported by slips 35 and casing head 31.

Received within the connector 50, as will be more fully understood hereafter is a subsurface safety valve 60 of a type that is known in the art. The valve 60 is hydraulically activated and when sufficient pressure is supplied thereto, it is opened, allowing production through the tubing string. When sufficient pressure ceases to be applied to the valve 60, it is closed, thereby blocking flow through the tubing string. In the exemplary embodiment described herein, fluid for operation of the valve 60 is supplied through the hydraulic oil string 46, annular space 48 within connector 50 and a port 49, which is in fluid-tight communication with valve 60. Fluid pressure may be maintained on the valve assembly 60 from a suitable pressure source (not shown) through the conduit 41 at the well platform 14.

As long as there is no damage to the well platform 14, oil string 46, upper tubing string portion 40a or associated platform equipment, the well is allowed to produce in a normal manner. If these components are damaged by collision with an ocean going vessel, hurricanes or any other destructive forces, pressure is interrupted to the subsurface safety valve 60, causing the valve to close, shutting in the well. Then, even if the entire upper portion of the tubing string 40a and the hydraulic oil string 46 are dislodged from the well, there will be no consequent release of fluids from the tubing string 40. Since both the upper portion of the tubing string 40a and hydraulic oil string 46 engage the connector 50 in a sliding connection, their removal is easily accomplished causing no damage to the connector 50 and the tubing string 40 therebelow. Even if the upper tubing string portion 40a and hydraulic oil string 46 are not completely displaced from the connector 50, they

may be easily removed by simply pulling upwardly thereon from the platform.

Then, the well may be killed, if desired, by lowering a kill string 70, as shown in FIG. 2, through the body of water 12 for connection with threads in the connector 50. Fluid may be pumped down the kill string 70 until a sufficient pressure is reached to open the valve assembly 60 or the valve may be removed. Fluid then flows down the tubing string 40 until a sufficient pressure is reached to kill the well. The well may be plugged at this time for abandonment, or if desired, repairs may be made to the platform 14 or any other damaged equipment, and then recompleted for resuming production.

Referring now to FIGS. 3A and 3B, the connector 50 and its relationship to tubing string 40, upper portion 40a and hydraulic oil string 46 will be described in detail. The connector 50 may comprise a tubular body portion 101, the lower end of which may be threaded for a pin and box connection 102 with support hanger 42. The support hanger 42 would in turn be supported by the surrounding production casing string 28 (see FIGS. 1 and 2) so that the connector 50 and the portion of tubing string 40 therebelow are supported independently of the well platform.

The internal diameter of the upper end of tubular body member 101 is increased so as to provide an upwardly extending collar or sleeve portion 103. The interior of the collar or sleeve portion 103 is engageable by seal assemblies 122, 123 and 124 carried on a seal nipple 120 which may be attached to the lower end of the tubing string upper portion 40a by a pin and box connection 126. The tubing string upper portion 40a extends upwardly to the well platform, as seen in FIG. 1, where it and nipple 120 are supported. The seals 122, 123 and 124 carried by nipple 120 are obviously longitudinally slidable within the interior of sleeve portion 103. Therefore, it is evident that the upper tubing string portion 40a and nipple 120 may be displaced upwardly from connector 50 by pulling upwardly on tubing string upper portion 40a. This sliding telescopic joint may also act as a slack joint for expansion and contraction of tubing due to temperature changes and movement of the well platform.

The interior of tubing body 101 below sleeve 103 is profiled to receive a subsurface safety valve, as shown in FIGS. 1 and 2. For example, groove 105 may be provided for latches carried by the valve. The type of valve contemplated for use herein is already known in the art. Such self-contained valves may comprise a closure member and an operator unit operable by hydraulic pressure. A port 49 is provided in the walls of body portion 101 for fluid communication with the valve operator. To provide a fluid passage from the hydraulic oil string 46 to the valve port 49, there is provided an outer sleeve assembly comprising, in the exemplary embodiment, a lower sleeve portion 131 and an upper sleeve portion 132. The sleeve assembly 131, 132 may be attached to the body 101 in any suitable manner. In the exemplary embodiment, this is accomplished by a threaded connection 133. Seal 135 assures that this is a fluid-tight connection. The sleeve assembly 131 and 132 is concentrically disposed relative to the body 101 and the lower end of tubing string upper portion 40a so as to leave an annular space 138 through which fluid may pass from the hydraulic oil string 46 to the valve port 49 for operation of the valve. The upper sleeve

portion 132 is of a larger internal diameter and may be conveniently attached to the lower portion 131 by a threaded connection 136. This connection is also made fluid-tight by the seal member 137.

The interior of upper sleeve portion 132 is adapted for sliding and sealing engagement with seal assemblies 141, 142, and 143 carried on a tubular sealing nipple or stem 145 attached to the lower end of oil string 46 by any suitable means, such as pipe collar 147. Like the tubing string seal nipple 120, the oil string nipple 145 also acts as a slack joint to compensate for temperature changes or movement of the platform, without affecting connector 50 or the tubing string 40 therebelow.

Thus, any damage to the platform, the tubing string upper portion 40a or oil string 46 does not affect the connector 50 or components of the well therebelow. Of course, if the oil string 46 is completely displaced from its telescopic engagement with upper sleeve portion 132, pressure is lost causing the valve carried by body 101 to close in the well. Even if the oil string seal 145 is not displaced by that much, the pressure system on the well platform may be adapted to interrupt pressure to the valve on predetermined damage to the platform. Then the hydraulic oil string 46 and nipple 145 may be removed, as the upper tubing portion 40a and its associated seal nipple 120, by simply pulling upwardly thereon.

After the upper tubing string portion 40a and hydraulic oil string 46 have been removed, it may be desirable to kill the well by pumping fluid down the tubing string 40. To accommodate a kill string, the upper interior of the lower portion 131 of the outer sleeve assembly may be provided with threads 150 suitable for this purpose. The threads 150 are normally submerged in the fluid in oil string 46. Thus, they are protected against corrosion or deleterious materials and are well lubricated for easy engagement. The upper portion 132 of sleeve assembly may act somewhat as a funnel or guide through which the lower end of the kill string may be guided toward engagement with the threads 150. Pressure may then be applied through the kill string causing the safety valve carried by the connector 50 to first be opened, or the valve may be removed, allowing fluids to be pumped through the string 40 into the producing formation, killing the well. After this, the well may be plugged and abandoned, or in some cases recompleted for resumption of production.

As can be seen from the foregoing description, the method and apparatus of the present invention provide a safe, reliable, simple way of completing a well for emergency reentry in the case of unforeseen platform damages. Thus, the expensive hazardous and unreliable methods of trying to shut in a well, known in the prior art, may be eliminated.

Although the present invention has been described for use with a single tubing string and an oil string concentrically disposed relative thereto, it is not so limited. For example, the joint 50 could be provided with a plurality of bores for receiving the sealing nipples of a plurality of upper tubing string portions and subsurface safety valves. In addition, the hydraulic oil strings could be smaller, individual tubing lying along side the tubing strings rather than surrounding them. In the case of a plurality of tubing strings, it is not necessary that the kill string be threadingly engaged with a tubing string. The necessary structural strength could be provided by the fluid engagement between the surrounding casing

and the nipple. Many other variations of the invention will be apparent to those skilled in the art. It is therefore intended that the scope of the invention be limited only by the claims which follow.

I claim:

1. A method of completing a well having a wellhead supported on a platform above a body of water and the well bore of which penetrates the floor of said body of water comprising the steps of:
 - a. running at least one casing string into said well bore;
 - b. cementing said casing string in said well bore;
 - c. running a first portion of a tubing string, having connector means on the upper end thereof, into said casing string;
 - d. suspending said first portion of said tubing string in said casing string at a point below said floor;
 - e. lowering a hydraulic conduit and a second portion of a tubing string through said body of water into sliding and sealing telescopic engagement with said connector means, leaving said hydraulic conduit and second tubing string portion free for sliding non-rotational disengagement from said connector means, said first and second tubing string portions being in fluidtight communication with each other;
 - f. suspending said hydraulic conduit and said second tubing string portion at said wellhead; and
 - g. installing a valve in said first string of tubing at a point below said floor and in fluidtight communication with said hydraulic conduit, through said connector means, so that said sliding non-rotational disengagement of said hydraulic conduit from said connector means interrupts said fluid communication with said valve closing said first portion of said tubing string.
2. A method of completing a well having a wellhead supported on a platform above a body of water and the well bore of which penetrates the floor of said body of water comprising the steps of:
 - a. running at least one casing string into said well bore;
 - b. cementing said casing string in said well bore;
 - c. running a first portion of a tubing string into said casing string;
 - d. suspending said first portion of said tubing string in said casing string at a point below said floor;
 - e. lowering a second portion of a tubing string through said body of water into sliding and sealing telescopic engagement with the upper end of said first tubing string portion; and
 - f. suspending said second tubing string portion at said wellhead;
 - g. a safety valve being installed in said first tubing string portion at a point below said floor, said safety valve being in fluid-tight communication with a hydraulic conduit which is lowered through said body of water and suspended from said platform, said hydraulic conduit surrounding said second tubing string portion so as to provide an annular space therebetween through which fluid may be conducted for hydraulic operation of said safety valve.
3. A method of completing a well as set forth in claim 2 characterized by the further steps of:
 - a. removing said hydraulic conduit and said second tubing string portion from said well;

- b. lowering another string of pipe through said body of water;
 - c. sealingly connecting said another string of pipe to the upper end of said first tubing string portion; and
 - d. killing said well by pumping fluids through said first tubing string portion.
4. A method of completing a well as set forth in claim 2 characterized in that said hydraulic conduit and said second tubing string portion are surrounded by a casing string extension extending upwardly through said body of water to said platform where it is supported.
5. A method of completing a well as set forth in claim 4 characterized by the further steps of:
- a. removing said hydraulic conduit and said second tubing string portion from said well; and
 - b. removing said casing string extension from said well;
 - c. lowering another string of pipe through said body of water into fluid-tight communication with said first tubing string portion; and
 - d. killing said well by pumping fluids through said another string and said first tubing string portion.
6. Apparatus for completion of a well having a wellhead supported on a platform above a body of water and the well bore of which penetrates the floor of said body of water comprising:
- a. at least one casing string cemented in said well bore;
 - b. a first portion of a tubing string supported within said casing string at a point below said floor;
 - c. a second portion of a tubing string telescopically engaging the upper end of said first portion in a sliding and sealing fit at a point below said floor, said second portion being supported in said wellhead at said platform, said second portion being free for sliding non-rotational disengagement from said upper end of said first portion;
 - d. valve means installed in said first tubing string portion;
 - e. connector means attached to the upper end of said first tubing string portion; and
 - f. a hydraulic conduit supported at said wellhead and extending through said body of water for engagement with said connector means and fluidtight communication with said valve means, said hydraulic conduit being free to interrupt said fluidtight communication upon non-rotational axial displacement from said connector means to actuate said valve closing said first tubing string portion.
7. Apparatus for completion of a well having a wellhead supported on a platform above a body of water and the well bore of which penetrates the floor of said body of water comprising:
- a. at least one casing string cemented in said well bore;
 - b. a first portion of a tubing string supported within said casing string at a point below said floor; and
 - c. a second portion of a tubing string telescopically engaging the upper end of said first portion in a sliding and sealing fit at a point below said floor, said second portion being supported in said wellhead at said platform; and
 - d. valve means installed in said first tubing string portion, said valve means being hydraulically operated by fluid conducted thereto by conduit means supported at said wellhead and extending through said body of water, said conduit means comprising a hy-

draulic pipe string surrounding said tubing string second portion and telescopically engaging the upper end of said tubing string first portion in a sliding and sealing fit.

8. Apparatus as set forth in claim 7 in which the upper end of said tubing string first portion is provided with connector means for said telescopic engagement with said tubing string second portion and said hydraulic string.

9. Apparatus as set forth in claim 8 in which said connector means comprises a first tubular sleeve means engaging said second portion and a second tubular sleeve means engaging said hydraulic string and surrounding said first sleeve means leaving an annular space therebetween through which said fluid for operation of said valve means is conducted.

10. Apparatus as set forth in claim 9 in which said second sleeve means comprises an upper tubular section the walls of which are engaged by seal means carried by said hydraulic string and a lower tubular section therebelow provided with threads.

11. Apparatus as set forth in claim 9 in which said connector means comprises a tubular support section below said first sleeve means for receiving said valve means.

12. Apparatus as set forth in claim 11 in which said support section has port means through its walls in fluid communication with said annular space between said first and second sleeve means.

13. Apparatus for completion of a well having a wellhead supported on a platform above a body of water and the well bore of which penetrates the floor of said body of water comprising:

- a. at least one casing string cemented in said well bore;
- b. a first portion of a tubing string supported within said casing string at a point below said floor; and
- c. a second portion of a tubing string telescopically engaging the upper end of said first portion in a sliding and sealing fit at a point below said floor, said second portion being supported in said wellhead at said platform;
- d. the upper end of said first portion of a tubing string comprising connector means telescopically receiving seal means carried by the lower end of said second tubing string portion, said connector means comprising first sleeve means for telescopically receiving said second tubing string lower portion and second sleeve means surrounding said first sleeve means for telescopically receiving the lower end of a conduit supported at said platform and surrounding said second tubing string.

14. Apparatus as set forth in claim 13 in which said connector means is provided with connection means engageable with corresponding connection means on another pipe string upon the removal of said second tubing string portion and said conduit.

15. Apparatus as set forth in claim 13 in which said connector means comprises support means for receiving valve means therein, said valve means being hydraulically operable by fluid supplied from said platform through said conduit and an annular space between said first and second sleeve means.

16. Apparatus as set forth in claim 15 in which the interior of said second sleeve means is provided with connection means engageable with corresponding connection means on another pipe string upon the removal of said second tubing string portion and said conduit.