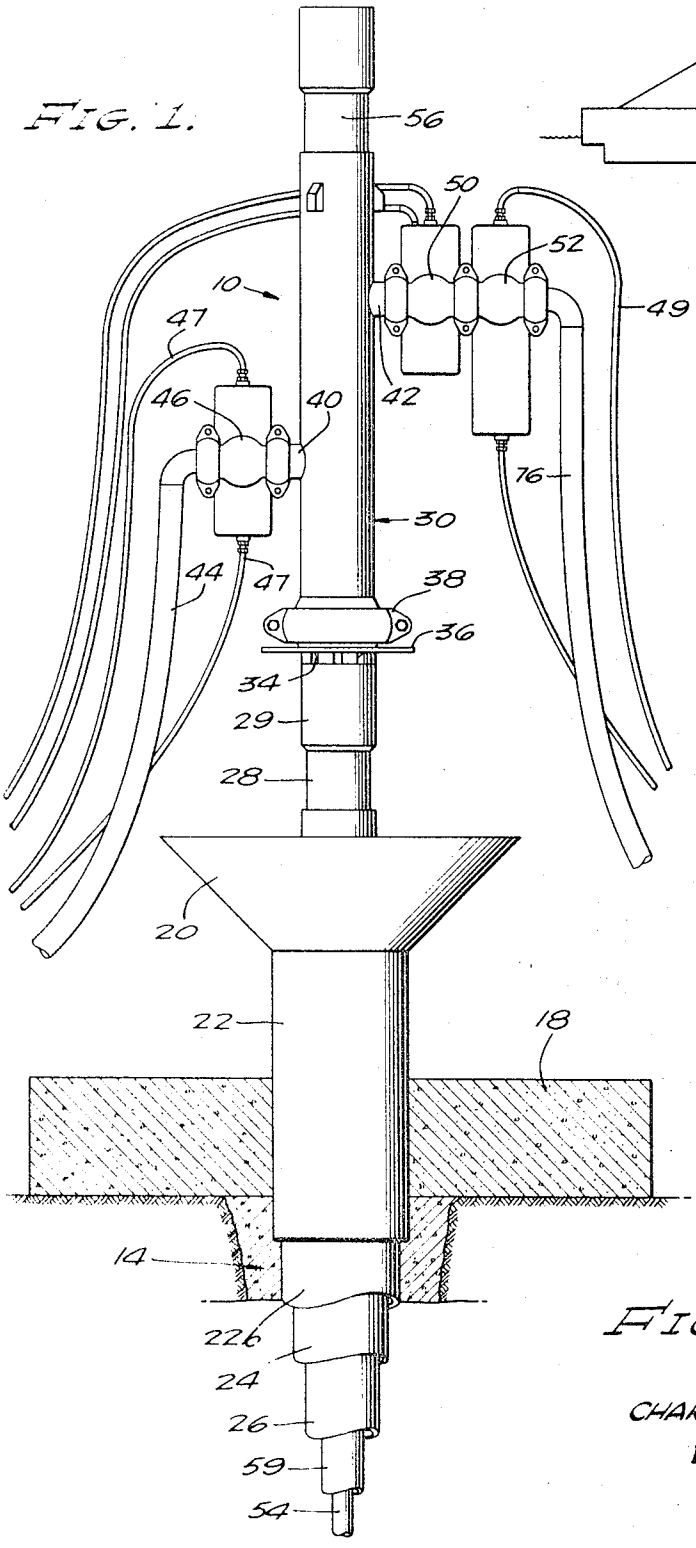
July 25, 1967 C. E. WAKEFIELD, JR 3,332,481

METHOD OF INSTALLING SUBMARINE DRILLING AND PRODUCTION HEAD

Original Filed April 3, 1961 4 Sheets-Sheet 1

FIG. 1.



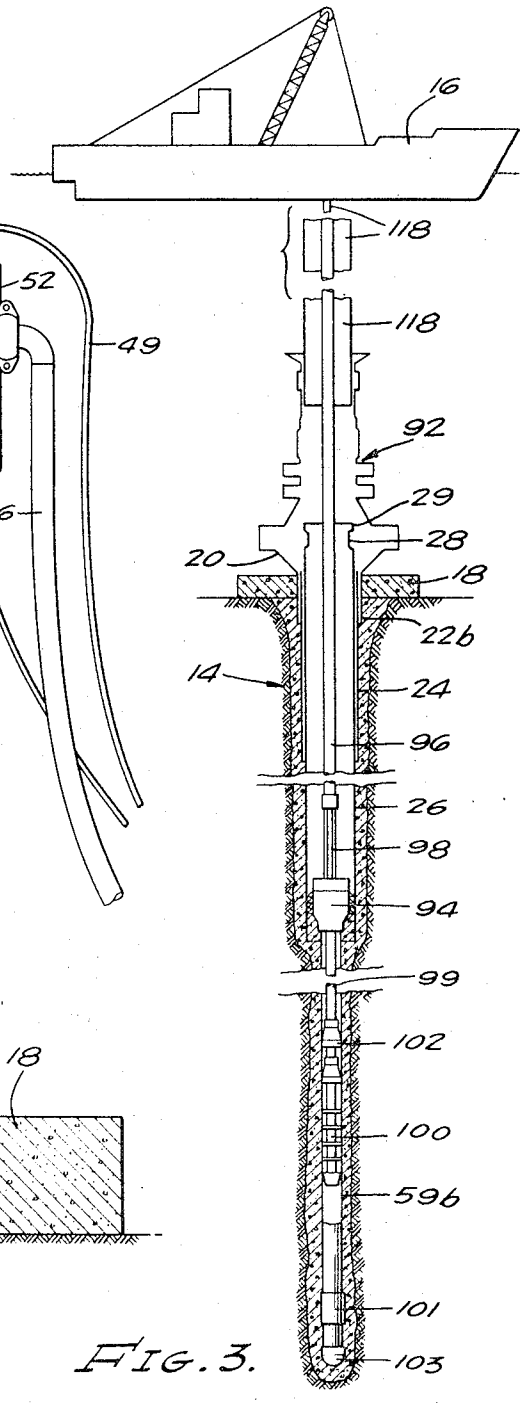


FIG. 3.

INVENTOR.
CHARLES E. WAKEFIELD, JR.
BY Donald W. Canady
ATTORNEY

July 25, 1967 C. E. WAKEFIELD, JR 3,332,481

METHOD OF INSTALLING SUBMARINE DRILLING AND PRODUCTION HEAD

Original Filed April 3, 1961 4 Sheets-Sheet 2

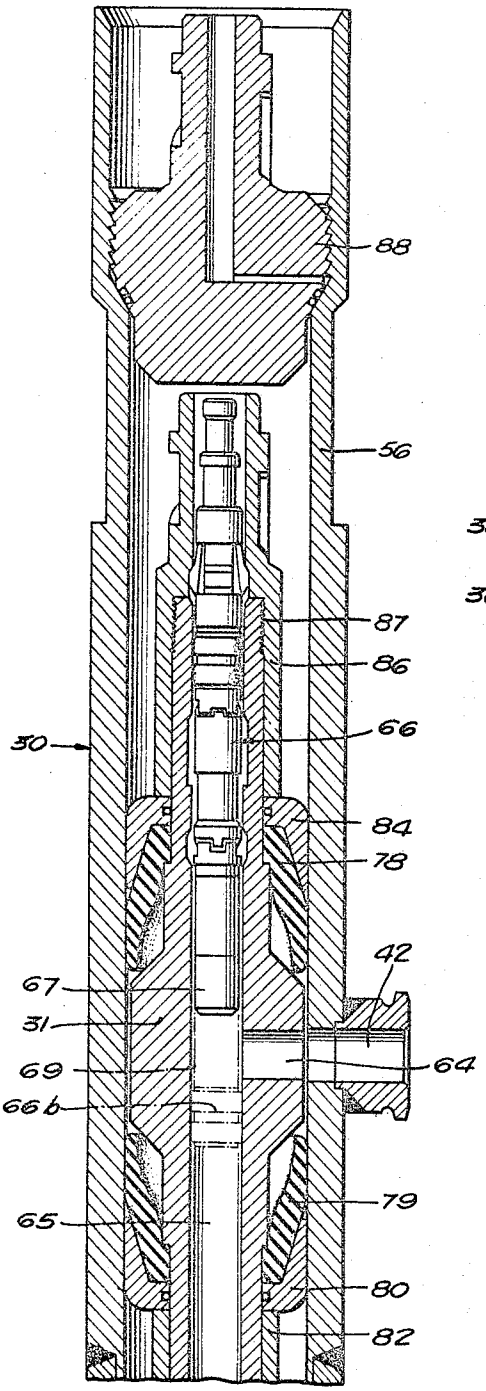


FIG. 2a.

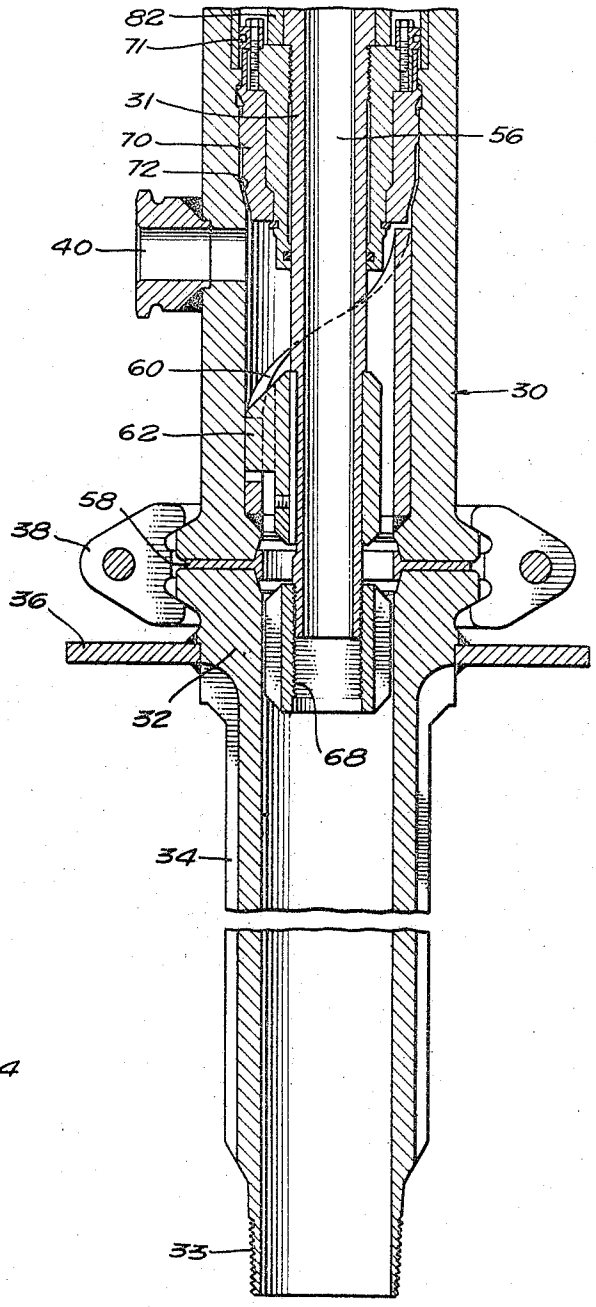


FIG. 2b.

INVENTOR.
CHARLES E. WAKEFIELD, JR.
BY Donald W. Canady
ATTORNEY

July 25, 1967 C. E. WAKEFIELD, JR 3,332,481

METHOD OF INSTALLING SUBMARINE DRILLING AND PRODUCTION HEAD

Original Filed April 5, 1961 4 Sheets-Sheet 3

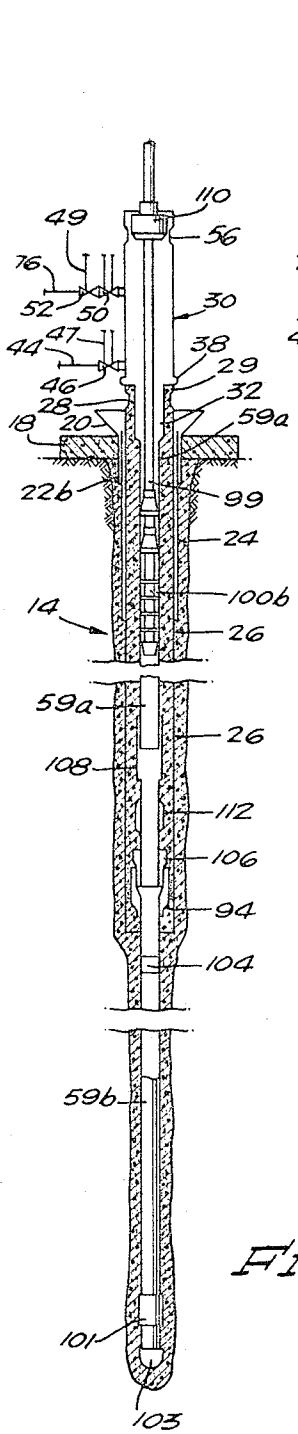


FIG. 4.

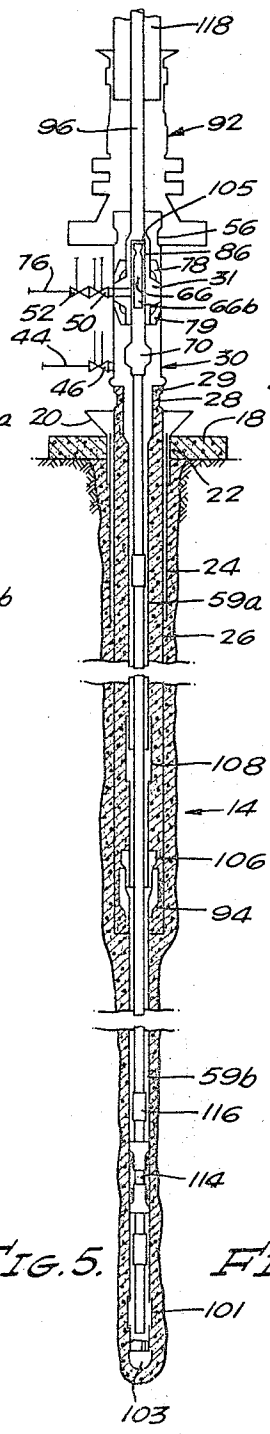


FIG. 5.

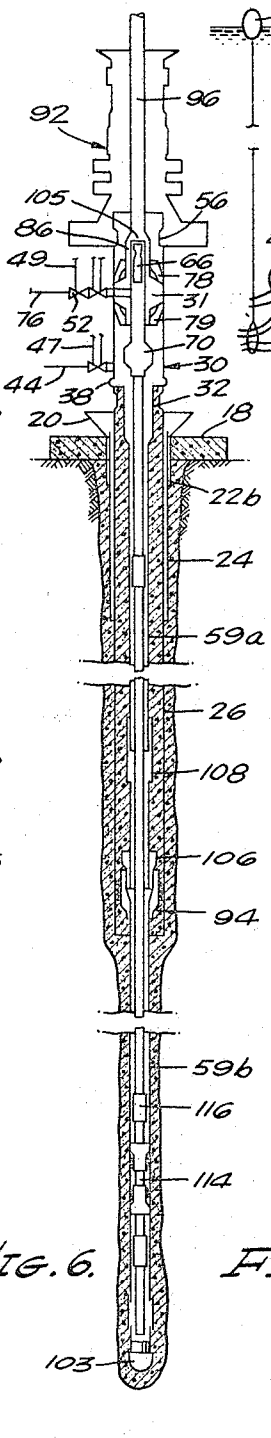


FIG. 6.

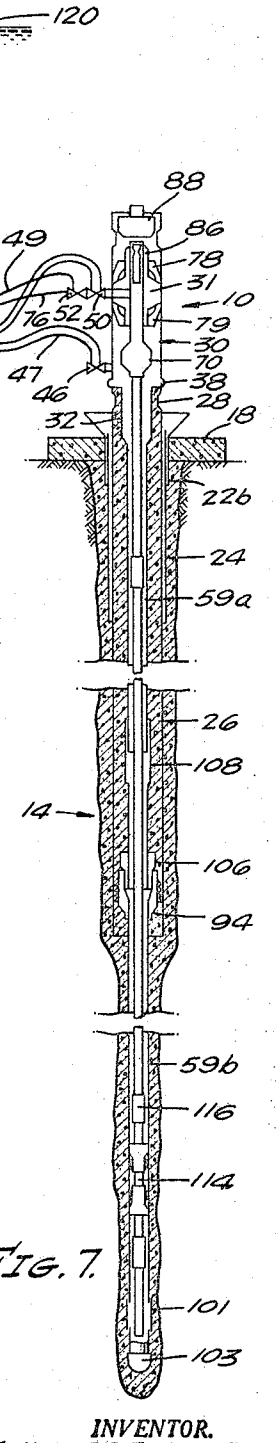


FIG. 7.

INVENTOR.
CHARLES E. WAKEFIELD, JR.
BY Donald W. Canady
ATTORNEY

July 25, 1967 C. E. WAKEFIELD, JR 3,332,481

METHOD OF INSTALLING SUBMARINE DRILLING AND PRODUCTION HEAD

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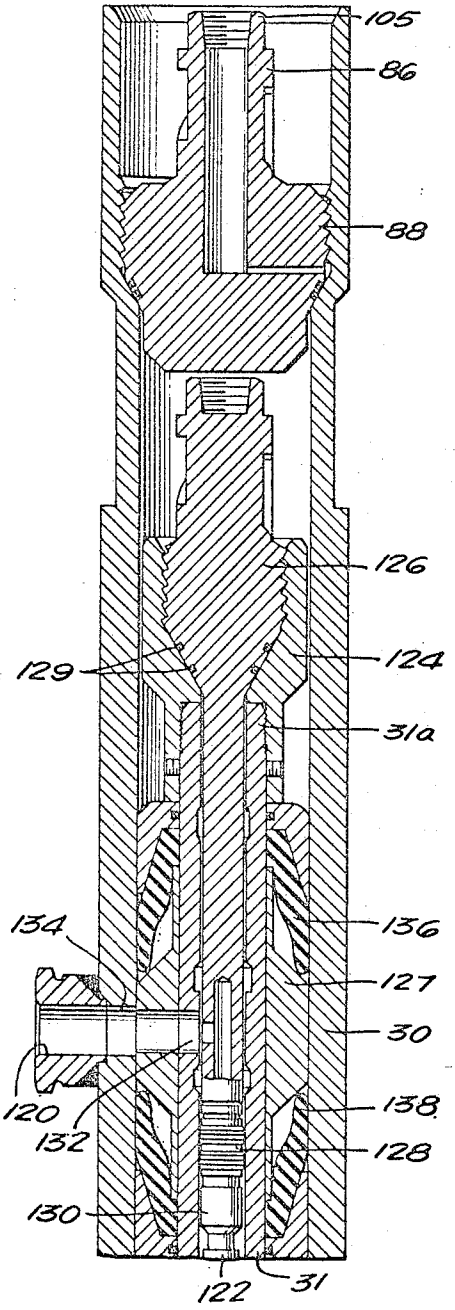


FIG. 8a.

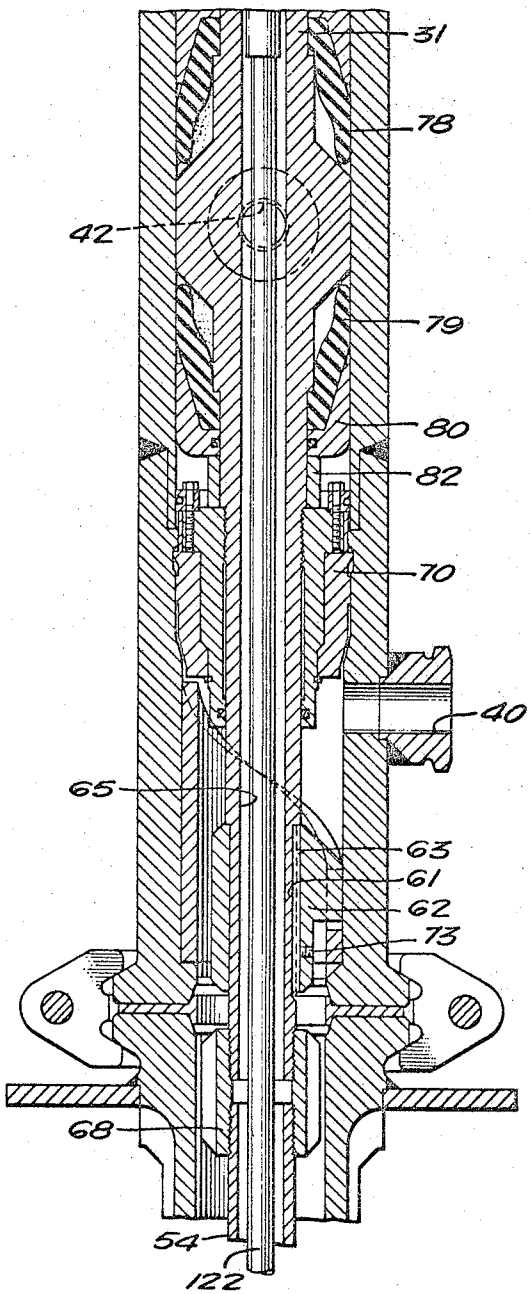


FIG. 8b.

INVENTOR.
CHARLES E. WAKEFIELD, JR.
BY Donald W. Canady
ATTORNEY

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3,332,481

METHOD OF INSTALLING SUBMARINE DRILLING AND PRODUCTION HEAD

Charles E. Wakefield, Jr., Long Beach, Calif., assignor to Richfield Oil Corporation, Los Angeles, Calif., a corporation of Delaware

Original application Apr. 3, 1961, Ser. No. 100,411. Divided and this application Oct. 20, 1965, Ser. No. 498,851

4 Claims. (Cl. 166—.6)

The present application is a divisional application of my copending application Ser. No. 100,411 filed Apr. 3, 1961, now U.S. Patent No. 3,279,536, and relates to the production of petroleum from a formation underlying a body of water, and more particularly, relating to a method for landing an underwater production head at the ocean floor.

When drilling into and producing from a stratum containing oil and gas under high pressure, a device known as a Christmas tree is normally utilized to control flow of oil and gas from the well during the period of natural flow. The Christmas tree comprises an assemblage of valves including generally, a master valve, one or more wing valves, and such flow constricting and gauging devices as may be required in a particular well. The outer casing is normally cemented into the well with the casing spool, the tubing head, the casing head, and the various Christmas tree components connected to the outer casing by bolting flanged fittings thereto. This, of course, requires working access to the wellhead during installation.

In offshore production methods heretofore known, the production head has been located at the surface of the water on a platform where workmen can easily flangeup a wellhead and Christmas tree. In deeper water, however, such platforms are obviously impractical and it has been proposed to locate the production head on the floor of the body of water. Installing a conventional Christmas tree on bottom, however, which has been done in some areas, necessarily requires costly diving operations.

It is therefore an object of my invention to provide a method for installing such production head beneath the water surface.

It is also an object of my present invention to provide a method for installing a submarine production head on the ocean floor at relatively deep depths.

It is also an object of my present invention to provide a method for installing a submarine production head remtely from a floating vessel.

Other objects and a fuller understanding of the invention may be had by referring to the following description and the appended claims taken in conjunction with the accompanying drawings, in which:

FIG. 1 is an elevation of my underwater production head showing its position relative to the well and submarine drilling base;

FIGS. 2*a* and 2*b* are divided longitudinal sectional views of the assembled production head showing the outer production mandrel and the inner tubing hanger mandrel assembly;

FIGS. 3 through 7 show the steps of the method for installing the production head in a well drilled into a formation underlying a body of water;

FIG. 3 is a side elevation in diagrammatic form showing the manner in which the inner casing is hung preparatory to landing the assembled production mandrel;

FIG. 4 is a side elevation in diagrammatic form showing the production mandrel positioned on the surface casing landing mandrel just above the landing base;

FIG. 5 is a diagrammatic side elevation showing the equipment used to run the tubing into the well;

FIG. 6 is a diagrammatic side elevation illustrating the means used to plug the production mandrel preparatory to bringing the well in;

FIG. 7 is a diagrammatic side elevation view showing the benthonic well in production;

FIGS. 8*a* and 8*b* are divided longitudinal sectional views of a modification of the production head shown in FIGS. 2*a* and 2*b* employing a second string of tubing with an additional side outlet communicating therewith.

Referring to the drawings, the invention is illustrated with reference to an underwater production head **10** which is adapted to be operated remotely either from a land base or a nearby offshore structure through control lines. The production head **10** serves the purpose of controlling the flow of gas and oil from the well **14** which function is normally performed by a Christmas tree and wellhead in land based operations. The assembled production head **10** is installed from a drilling barge **16** so that is can subsequently be remotely controlled from land at the completion of the drilling operation when the top opening is plugged off above the tubing outlet.

In another embodiment of the above device the bore of the production head assembly shown in FIG. 2 is enlarged to permit drilling operations and the passage of casing therethrough, thus obviating the need for separate installation of the production head at the conclusion of the drilling operation.

Referring now to FIG. 1, a landing base **18** with a funnel member **20** and a sleeve **22** which guide drilling tools and various well equipment through the landing base is positioned on the ocean floor at the well opening. The lower portion **22***b* of the sleeve **22** is affixed to sleeve **22** in such a manner that the joint forms a seat on which the conductor pipe **24** rests as shown in copending application Ser. No. 19,722, of William D. Leake, filed Apr. 4, 1960, and now U.S. Patent 3,236,308. A surface pipe **26** is equipped with external lugs (not shown) which support the surface pipe within the conductor pipe **24**. The surface pipe **26** is provided at its upper extremity with a landing mandrel **29** onto which the blowout prevention equipment is latched during the drilling operation.

The production head **10** includes a production mandrel **30** which is clamped together in two pieces, the lower portion **32** of which may be provided with splines **34** and cemented into the surface pipe. The production mandrel **10** functions as one piece and can be constructed as one unit, however, as a prevention measure I prefer to divide the outer mandrel into two pieces as shown to facilitate removal of the upper part of the mandrel should the need arise after the lower portion **32** has been cemented into the surface pipe. A sealing member **58** is positioned between the production mandrel and the lower splined portion **32**. Portion **32** is equipped with a baffle **36** beneath the clamps **38** which serves to protect the clamps from cement returns. The production mandrel has a latching neck **56** near its upper end onto which the blowout prevention equipment may be latched while the tubing **54** is being run into the well.

The production mandrel **30** is provided with a casing outlet **40** and a tubing outlet **42** through which latter outlet the flow of oil and gas from the well **14** is controlled. A casing flow line **44** is provided at the outlet **40** and a casing valve **46** is positioned at the outlet **40** and hydraulically actuated through fluid control lines **47**. The casing outlet may be used initially to circulate drilling fluid from the well, however, it is normally closed during the period of natural flow. Valve **46**, preferably, is a conventional nonlubricated plug valve equipped with a conventional hydraulic actuator.

The tubing outlet **42** is equipped with a hydraulically actuated control valve **50** similar to casing valve **46**, and a second spring loaded safety valve **52** held open with

hydraulic pressure, which together control the flow of gas and oil from the well through the flow tube 54.

The production head 10 has an outer or production mandrel 30 and an inner or tubing hanger mandrel 31 as shown in detail in FIGS. 2*a* and 2*b*.

Water shutoff casing 59 is threaded to the lower end of the production mandrel 30 at 33 and the production tubing 54 is threaded into the lower end of the tubing hanger mandrel at 68. An orientation cam 60 inside the production mandrel 30 is adapted to receive orientation lug 62 on the tubing hanger mandrel 31 only in such a manner that the side opening 64 in the tubing hanger mandrel 31 registers with the tubing outlet 42 in the production mandrel 30. In FIG. 2*b*, the orientation cam 60 and the lug 62 have been rotated 180° for the ease of illustration. As best viewed in FIG. 8*b*, orientation lug 62 has an internal keyway 63 which is aligned with keyway 61 provided in the tubing hanger mandrel 31. A key held in place by set screw 73 is fitted in the aligned keyways 63 and 61 to prevent the orientation lug 62 from rotating relative to the tubing hanger mandrel 31.

The tubing hanger mandrel bore 65 is plugged above the side outlet 64 with any suitable means which can be inserted remotely, such as the Otis type "S" packing mandrel assembly 66 which can be fitted into sealing position on a wire line. The cap 67 of packer assembly 66 can be removed and a second packer 66*b* added to the packer assembly on an extension 69 to seal off tubing outlet 64.

Tubing 54 is threaded into a coupling member 68 which in turn is threaded to the lower end of the tubing hanger mandrel 31. The tubing and the tubing hanger mandrel are supported within the production mandrel with a suitable tubing hanger member such as the automatic tubing hanger 70, on internal tapered portion 72 of the production mandrel. The automatic tubing hanger 70 hangs the tubing in the production head automatically without the use of manually tightened ring nuts or locking screws. The hanger, supporting the tubing string, seats on a tapered bowl 72 in the tubing head and is locked against upward movement by spring dogs 75. As the hanger 70 enters the production mandrel 30, the spring dogs 75 surrounding the upper part of the hanger are retracted and the hanger slides down until, as shown in FIGS. 2*b* and 8*b*, the dogs spring automatically into the groove or shoulder 75*a* provided in the production mandrel. Downhole pressure from below the tubing hanger actuates or locks the automatic tubing hanger by moving the packing unit 77 upward which, in turn, locks the spring dogs securely into groove 75*a*.

During production, oil and gas flows through tubing 54 and up through tubing hanger mandrel bore 65, out the registering tubing outlets 64 and 42 through the hydraulically controlled valves 50 and 52 and thence through flow line 76 to storage tanks. Packer cups 78 and 79 which may advantageously be of the self sealing or pressure energized type, seal against leakage between the production mandrel and the tubing hanger mandrel at their tubing outlets. The tubing hanger seals 71 are the primary seals between the tubing and the casing against upward flow through the casing annulus 41 above casing outlet 40. Packer cup 79 also serves as a secondary seal behind primary seals 71, to restrict flow between the tubing and casing to the casing outlet 40. Packer cup 79 is supported by a thimble 80 which is supported on the automatic tubing hanger 70 by a sleeve 82. Packer thimble 84 is supported in place by the safety joint part 86 which is threaded to the tubing hanger mandrel at 87.

A variation of the production head is shown assembled in FIGURES 8*a* and 8*b*. In this modification a macaroni string 122 is supported within the tubing hanger mandrel 31. A tubing hanger mandrel adapter 124 is threaded to the upper end of the tubing hanger mandrel 31 and has a macaroni hanger 126 threaded therein on which the inner or macaroni string of tubing 122 is hung with a coupling member 130. Packing member 128 seals off flow between tubing 122 and the tubing hanger mandrel above the tubing outlet 42, and sealing elements 129 serve as secondary seals. The upper end of the macaroni hanger 126 is socketed similar to the upper end of the head plug 88 and the safety joint 86 so that the tubing hanger mandrel or the macaroni string 122 can be removed on a socket coupling (not shown) attached to the drill string. The upper end 31*a* of the tubing hanger mandrel is provided with an additional outlet 132 which communicates with outlet 134 in the production mandrel, thus providing communication between the macaroni tubing 122 and the outlet 120. As an example of the second recovery techniques for which this macaroni tubing may be employed, gas may be injected into the outlet 120 and through the macaroni tubing to effect a gas lift.

Packers 136 and 138 (FIG. 8*a*) are provided above and below the macaroni outlet 120 to seal between the production mandrel 30 and the upper portion 127 of the tubing hanger mandrel. In FIG. 8*b* the tubing outlet 42 is shown in phantom since in this modification outlet 42 would not be in the same plane with the casing outlet 40 and macaroni outlet 120. In the modification shown in FIGS. 8*a* and 8*b* the production head apparatus below the tubing outlet 42 would be essentially the same as in the production head described above.

In operation the production mandrel is first landed on the surface casing landing mandrel with a suitable landing sub, then the assembled tubing hanger mandrel with tubing connected thereto is lowered into place on the drill pipe with the socket end of a safety joint attached to the lower end thereof, after which the plug 66 is set on a wire line. A head plug 88 is then lowered on the socket end of the safety joint (not shown) and screwed into the production mandrel. The head plug 88 is designed to limit upward movement of the tubing hanger mandrel in the event of a blowout and serves as a secondary seal above packer cup 78 and plug 66.

The underwater production head of the present invention is landed at the benthos well from a drilling vessel 16 such as is disclosed in detail in copending application Ser. No. 19,722, of William D. Leake, filed Apr. 4, 1960, and now U.S. Patent No. 3,236,308. With the blowout prevention equipment 92 latched to the latching neck 28 of the surface casing landing mandrel 29 the lower section of casing 59*b* is hung on a conventional casing hanger 94 which is lowered into the surface pipe on the drill pipe 96, as shown in FIG. 3. A suitable release tool 98 is used to release the drill pipe from the casing hanger.

A tubing tail 99 is run through the casing hanger and the lower section 59*b* of the casing is cemented up to the casing hanger. A flexible cement plug 100 is provided to divide the cement from the drilling mud and a down swab 102 prevents the cement from coming back up the casing. A float collar 101 and a float shoe 103 are provided in the conventional manner at the lower end of the casing to prevent cement from coming back up the inside of the casing after displacement of the cement.

After the lower section of casing is cemented in the surface pipe the casing is sealed off internally with a bridge plug or a cement plug 104 and the blowout prevention equipment removed from the wellhead, as shown in FIG. 4. The production mandrel 30 with the upper section of casing 59*a* threaded thereon is lowered into the surface pipe on the drill pipe with a landing sub 110. A suitable casing splice 106 is provided to splice the lower section 59*b* of the casing to the upper section 59*a* of the casing. A flexible slip joint 108 may be provided in the casing between the upper and lower sections of casing.

In shallow drilling operation setting the casing in two parts may not be necessary and hence the entire casing can be hung from the production mandrel.

The tubing tail **99** is withdrawn to the barge to attach a second flexible plug **100***b* and then the upper section **59***a* of the casing is cemented through a stage cement collar **112**. Thus, the casing and the splined lower portion **32** of the production mandrel are cemented into the surface pipe **26** and surface casing landing mandrel **29**. The baffle **36** prevents cement returns from contacting the clamp **38**. The surface pipe and conductor pipe were previously cemented into the well.

When the production head is used as a drilling head, the casing is hung from the inside of the enlarged production mandrel, for example, on a donut hanger, and the surface casing is threaded to the lower end of the production mandrel.

The blowout prevention equipment **92** is replaced on the production mandrel by latching the blowout prevention equipment to the latching neck **56** of the production mandrel. The casing riser **118** which was used in the drilling operation is then lowered and latched into the upper end of the blowout prevention equipment **92**. After the casing plug **104** is drilled out or retrieved, the tubing is hung on the tubing hanger mandrel and the tubing hanger mandrel lowered into the production mandrel, as shown in FIG. 5. The socket end **105** of the safety joint is threaded to the drill pipe **96** and releasably latches the safety joint **86** of the tubing hanger mandrel to the drill pipe to lower the mandrel assembly into the well. The lower end of the tubing is provided with a special packer **114** which is a means of confining zone pressure. Above this packer a sliding side door **116** is provided for circulating mud out of the hole after the tubing is run into the casing.

Before the tubing hanger mandrel is lowered through the blowout prevention equipment, plug **66** with an extension **69** and second packer **66***b* which seals the bore of the tubing hanger mandrel below the tubing outlet, is lowered into the tubing hanger mandrel to seal off the tubing outlet of the tubing hanger mandrel until the mandrel is lowered through the blowout preventers and the tubing outlet put in communication with the tubing outlet valves **50** and **52**. After the tubing hanger mandrel **31** is lowered into place, however, the plug **66** is pulled up to the barge and the second packer **66***b* and extension **69** are removed and a cap **67** screwed into the plug **66** to seal off the tubing above the tubing outlet **64** and permit tubing flow through the outlet. A head plug **88** is then threaded into the production mandrel **30** with the socket end **105** of the safety joint attached to the drill pipe **96**. This plug **88** serves as a secondary seal above the packer cup **78** and also is a secondary seal to the plug **66** as well as a safety device to prevent the tubing hanger mandrel from blowing out of the hole.

At the conclusion of the drilling and cementing operations and after the well is brought in, the drill pipe and casing riser are withdrawn to the barge and the blowout prevention equipment retrieved. The production of fluid from the well is then controlled remotely from a shore control center or a control barge. Flow line **76** is connected to the fail-safe valve **52** and run on the ocean floor with the safety valve control line **49** to a tank (not shown). The casing outlet hose **44** and the remainder of the control lines are then blanked off and dropped on bottom. A buoy marker **120** is attached to the blanked off control lines and casing outlet hose as shown in FIG. 7.

Although I have described my present invention with a certain degree of particularly in order to set forth the best mode of operation, it is to be understood that my invention is not to be limited to the details set forth but should be given the full scope of the appended claims.

I claim:

1. In a method for installing a production head at a well drilled in a formation underlying a body of water wherein a surface casing has been cemented in the well, the steps comprising:

hanging the lower portion of a water shutoff casing inside said surface casing,

securing the upper portion of said water casing to the lower end of a production mandrel,

lowering said production mandrel with said upper portion of said water shutoff casing onto said well whereby said upper portion of said water shutoff casing engages said lower water shutoff casing portion,

securing production tubing to the lower end of a second mandrel,

lowering said second mandrel with said tubing into said production mandrel whereby said tubing extends into said water casing, and

preventing flow through the upper end of said production mandrel.

2. In a method for installing a production head at a well drilled in a formation underlying a body of water wherein a surface casing has been cemented in the well, the steps comprising:

hanging the lower portion of a water shutoff casing inside said surface casing,

securing the upper portion of said water casing to the lower end of a production mandrel having a side outlet,

lowering said production mandrel with said upper portion of water shutoff casing onto said surface casing whereby said upper casing portion engages said lower casing portion,

securing production tubing to the lower end of a second mandrel having a side outlet,

lowering said second mandrel with said tubing into said production mandrel whereby said tubing extends into said water casing,

registering said second mandrel side outlet with said production mandrel side outlet, and

preventing flow through said mandrels.

3. In a method for installing a production head at a well drilled in a formation underlying a body of water wherein a surface casing has been cemented in the well, the steps comprising:

hanging the lower portion of a water shutoff casing inside said surface casing,

cementing said lower casing to said formation and said surface casing,

securing the upper portion of said water casing to the lower end of a production mandrel,

lowering said production mandrel with said upper casing portion onto said surface casing, said upper casing portion splicing with said lower portion,

cementing said upper portion and the lower portion of said production mandrel into said surface casing,

securing production tubing to the lower end of a second mandrel,

lowering said second mandrel and said tubing into said production mandrel whereby said tubing extends into said water casing, and

preventing flow through said mandrels.

4. In a method for installing a production head at a well drilled in a formation underlying a body of water wherein a surface casing has been cemented in the well, the steps comprising:

securing a water shutoff casing to the lower end of a production mandrel having a side outlet,

lowering said production mandrel onto said well whereby said water casing is lowered into said surface casing,

securing production tubing to the lower end of a second mandrel having a side outlet,

sealing between the side outlet of said second mandrel and the bore of said second mandrel,

lowering said second mandrel with said tubing into said production mandrel,

registering said second mandrel side outlet with said production mandrel side outlet,

removing said side outlet seal after said second mandrel is lowered into said production mandrel.

sealing the bore of said second mandrel above said side outlet, and

plugging said production mandrel above the top of said second mandrel.

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CHARLES E. O'CONNELL, *Primary Examiner.*

R. E. FAVREAU, *Assistant Examiner.*