Dec. 20, 1966 J. A. HAEBER 3,292,695

METHOD AND APPARATUS FOR PRODUCING UNDERWATER OIL FIELDS

Original Filed Sept. 12, 1963 4 Sheets-Sheet 1

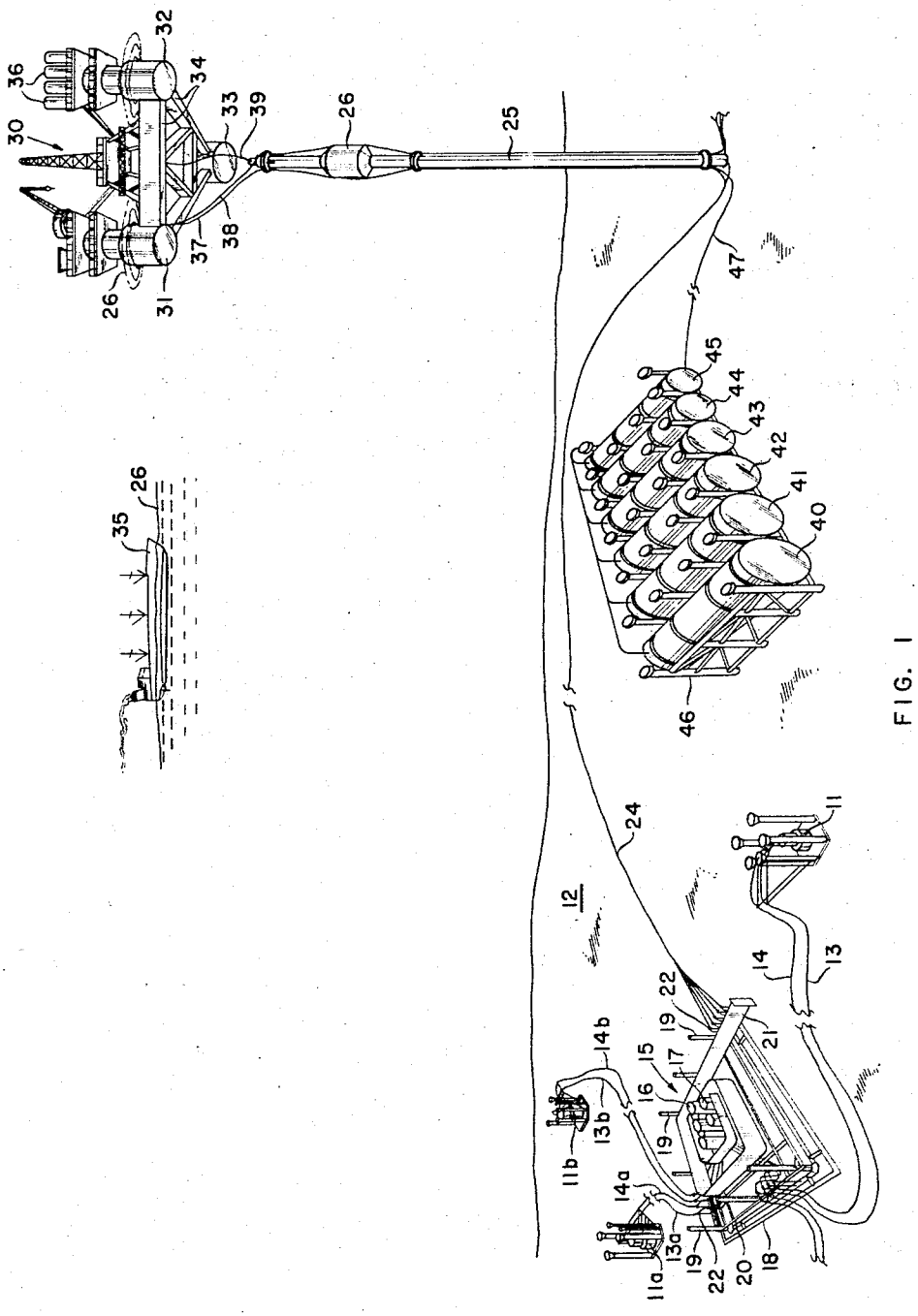


FIG. 1

INVENTOR:
JOHN A. HAEBER
BY: A. H. McCarthy
HIS AGENT

Dec. 20, 1966 J. A. HAEBER 3,292,695

METHOD AND APPARATUS FOR PRODUCING UNDERWATER OIL FIELDS

Original Filed Sept. 12, 1963 4 Sheets-Sheet 2

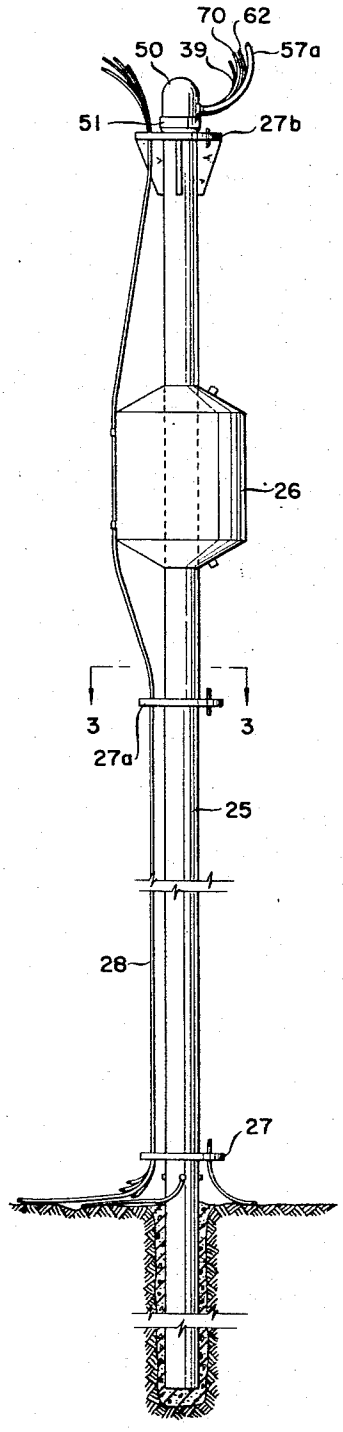


FIG. 2

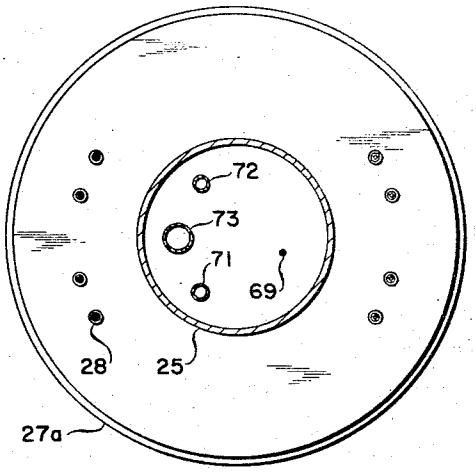


FIG. 3

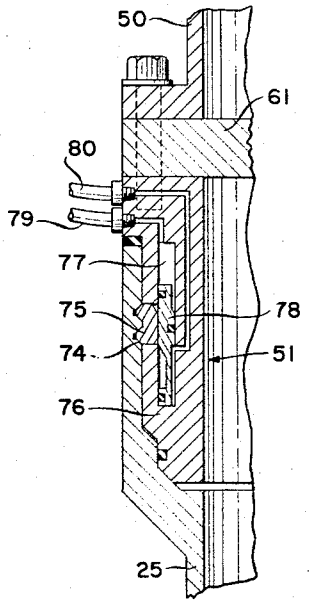


FIG. 9

INVENTOR:
JOHN A. HAEBER
BY: A. H. McCarthy
HIS AGENT

METHOD AND APPARATUS FOR PRODUCING UNDERWATER OIL FIELDS

Original Filed Sept. 12, 1963 4 Sheets-Sheet 3

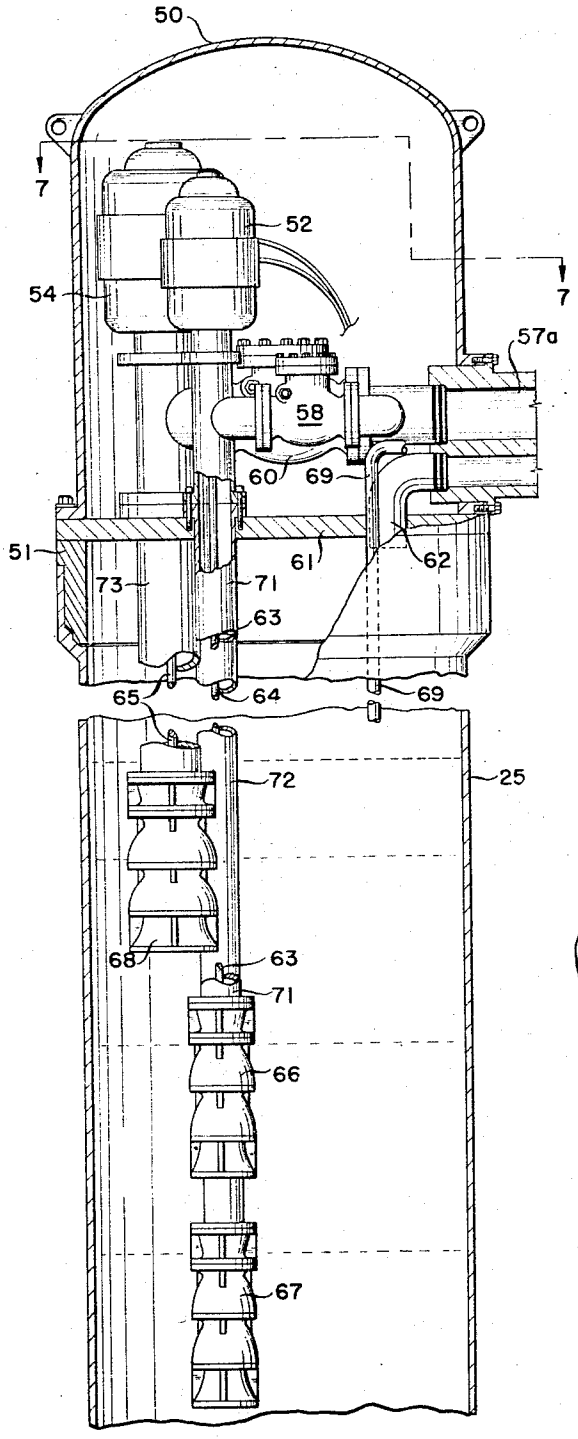


FIG. 4

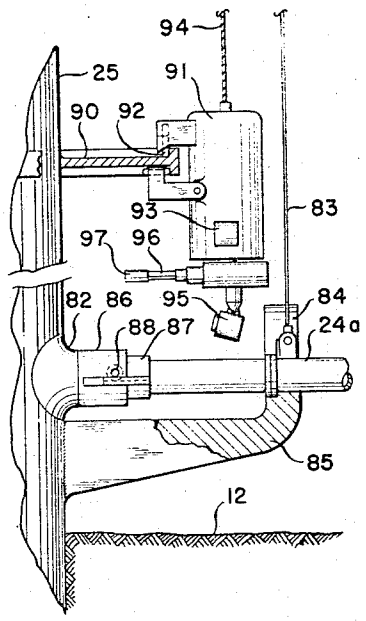


FIG. 5

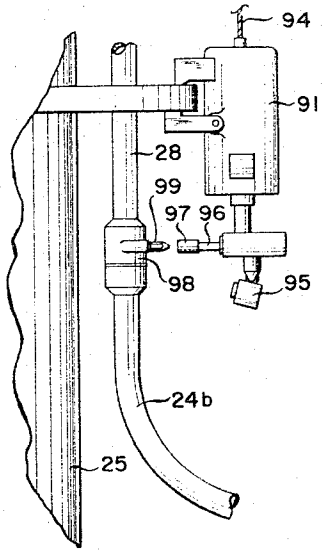


FIG. 6

INVENTOR:
JOHN A. HAEBER
BY: A. H. McCarthy
HIS AGENT

METHOD AND APPARATUS FOR PRODUCING UNDERWATER OIL FIELDS

Original Filed Sept. 12, 1963 4 Sheets-Sheet 4

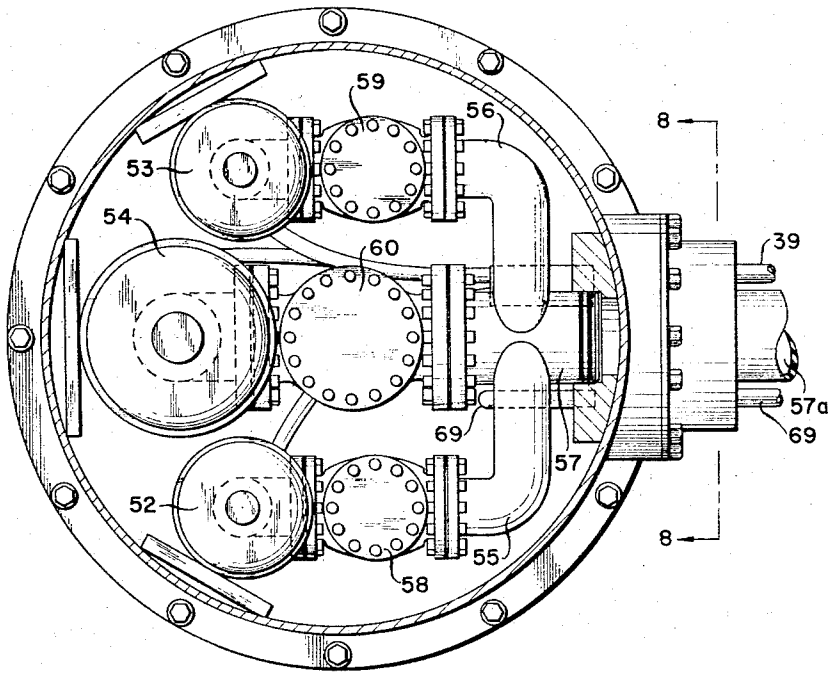


FIG. 7

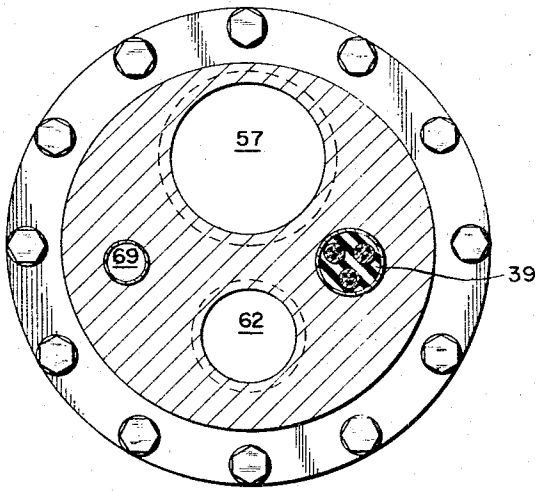


FIG. 8

INVENTOR:
JOHN A. HAEBER
BY: J. H. McCarthy
HIS AGENT

United States Patent Office 3,292,695
Patented Dec. 20, 1966

3,292,695

METHOD AND APPARATUS FOR PRODUCING UNDERWATER OIL FIELDS

John A. Haeber, Houston, Tex., assignor to Shell Oil Company, New York, N.Y., a corporation of Delaware

Original application Sept. 12, 1963, Ser. No. 308,531. Divided and this application July 21, 1965, Ser. No. 484,153

2 Claims. (Cl. 166—.5)

The present application is a divisional application of copending application Serial No. 308,531, filed September 12, 1963.

This invention is directed to methods and apparatus for producing underwater oil and gas fields wherein the wellhead assembly mounted on the top of each well is positioned at a substantial distance below the surface of a body of water and is preferably positioned on the ocean floor.

A recent development in the oil industry is the development of oil and/or gas fields which are located underwater and oftentimes at a substantial distance, say 5 to 100 miles offshore. Since well structures which extend to a point about the surface of the water form navigation hazards for ships operating in the vicinity, a new development has been the placement of the wellhead assemblies on the ocean floor. Wells of this type are presently produced by running the production flow lines from the well to shore or to a stationary production facility mounted on piles at an offshore location. The use of flow lines running to shore limits the production of wells located many miles from shore as the oil-producing formation which is traversed by the well must be under substantial pressure so as to provide sufficient pressure to produce the oil and other well fluid up the well and then to overcome the frictional resistance encountered in the many miles of flow line extending to shore. On the other hand, the use of stationary production platforms is limited to rather shallow water depths as it is very costly to install such platforms in deep water and the cost would be prohibitive to construct and install stationary platforms for oil field purposes in deep water say over 400 feet in depth.

It is therefore a primary object of the present invention to provide apparatus and methods for producing underwater oil fields wherein the wellhead assemblies are positioned on the ocean floor in water of any depth.

A further object of the present invention is to provide methods and apparatus for reducing or minimizing, the well's tubing pressure (pressure in the production tubing at the wellhead) and thereby (1) prolong the wells' period of nautral flow (if any), (2) increase the production rate of the well and (3) reduce the amount of lift gas required to produce the well after natural flow has either ceased or declined to where the use of lift gas is beneficial.

Another object of the present invention is to provide methods and apparatus for supporting flow lines and other field collecting and distribution lines extending from the ocean floor to a position near the surface of a body of water.

A still further object of the present invention is to provide apparatus for supporting vertically-extending well flow lines and other field collecting and distributing lines above the ocean floor while providing means for connecting the flow lines to a suitable vessel at the surface for receiving the production fluid from the wells.

Still another object of the present invention is to provide apparatus for handling a multiphase production fluid from an underwater oil field whereby the gaseous phase of the production fluid may be separated from the oil phase before the oil phase is raised above the ocean floor.

Still another object of the present invention is to provide a method and apparatus for separating a multiphase oil production fluid in a vessel at the surface of the ocean and returning the oil phase of the production fluid down to storage facilities positioned on the ocean floor.

These and other objects of this invention will be understood from the following description when taken with reference to the drawing, wherein:

FIGURE 1 is a synoptic view illustrating an underwater oil field having a plurality of wells drilled therein and connected to a production facility on the ocean floor which in turn is connected in fluidtight communication with a vertically-extending cylindrical structure positioned in the ocean floor and extending upwardly to a point near the ocean surface where it is connected with a floating vessel or production facility on the surface, the production facility on the surface also being in communication with suitable storage tanks located on the ocean floor;

FIGURE 2 is a longitudinal view diagrammatically illustrating the vertically-extending elongated cylindrical structure which extends into the ocean floor and is anchored therein;

FIGURE 3 is an enlarged cross-sectional view taken along the line 3—3 of FIGURE 2;

FIGURE 4 is an enlarged longitudinal view, taken partially in cross-section, illustrating a pump mechanism carried within the vertical cylindrical structure of FIGURE 2;

FIGURES 5 and 6 are fragmental views, taken partially in cross-section, illustrating one method of connecting underwater piplelines to the vertical cylindrical structure of FIGURE 2;

FIGURE 7 is a cross-sectional view taken along the line 7—7 of FIGURE 4;

FIGURE 8 is a cross-sectional view taken along the line 8—8 of FIGURE 7; and,

FIGURE 9 is a fragmental view taken in the longitudinal cross-section of one form of a means for connecting pumping apparatus to the top of the vertical cylindrical structure of FIGURE 2.

Referring to FIGURE 1 of the drawing, a plurality of underwater wells are illustrated with their wellhead assemblies **11**, **11***a* and **11***b* positioned on the ocean floor **12**. Each production wellhead assembly, for example wellhead assembly **11** is provided with a least one flow line **13** and preferably two flow lines **13** and **14** whereby the well production fluid may be taken away through one line, and if necessary, gas may be pumped down through the other line during later well life in order to produce the well. The other wellhead assemblies **11***a* and **11***b* are also provided with dual flow lines **13***a*, **14***a* and **13***b*, **14***b*, respectively.

The production flow lines from the various underwater wells preferably lead to a production facility, generally represented by numeral **15**, which is located on the ocean floor and is normally centrally located among the wells which are connected to it. The production facility **15** may be of various types. For example, the production facility **15** may be merely a manifolding station where the production fluids from the several wells are combined so that they can be delivered by a single flow line to a distant terminal. On the other hand, the production facility **15** may also be provided with suitable metering devices for metering the individual flow from each of the wells prior to combining the several flows and sending them to the distant terminal.

As most oil is combined with gas in many oil fields, the production facility **15** is preferably provided with suitable separators **16** for separating the gas from the oil before flowing the oil to the distant terminal. While high pressure gas separators **16** may be employed early in the life

of the well, the production facility **15** is also preferably provided with low pressure gas separators **17** for use during the latter part of the well life. The production facility **15** may have a base frame **18** secured to the ocean floor and equipped with guide columns **19** on which a central removable frame **20** is positioned. The various manifolding lines and separators **16** and **17** are secured to and are removable with the inner rfame **20** which is also preferably provided with a track **21**. The track is employed in order to facilitate ease of positioning an underwater manipulator device adapted to open and close valves or to connect or disconnect various flow lines one from the other. Each of the flow lines coming to the production facility **15** is provided with a remotely-actuatable pipe connector **22** of any type well known to the art so that the flow lines may be disconnected from the production facility **15** before the central removable frame **20** and its associated equipment are pulled back to the surface for maintenance or repairs.

The flowlines coming from the production facility **15** may be bound together in the form of a single bundle of lines **24**, as illustrated in FIGURE 1. If the production facility **15** is merely a manifolding station, only a single flowline **24** would be needed during the early life of the wells. However, if the wells were produced by gas lift during the latter part of their life, the bundle of lines **24** should at least consist of a production flowline away from the production facility **15** and a gas line extending to the production facility **15** and thence on to the individual wells **11**, **11***a*, and **11***b*. In the event that the production facility **15** also includes gas separation apparatus, the bundle of lines **24** should preferably include separate gas lines for high and low pressures to and from the high and low pressure gas separators **16** and **17**, respectively. Additional lines may connect the production facility **15** with a distant terminal so that various types of well maintenance tools or instruments can be pumped down to the production facility **15** or to any of the individual wells for carrying out certain selected operations. It is to be understood that in an oil field having a great number of wells a plurality of production facilities **15** would be strategically located among the many wells.

Positioned at some distance from the production facility **15** is a free-head pile in the form of a large-diameter elongated and vertically-positioned cylindrical structure having its lower end closed in a fluid-tight manner and sunken and anchored to the ocean floor. The upper end of the elongated tubular or cylindrical structure is located below the surface **26** of the ocean so as to be relatively unaffected by wind and wave forces and so that it does not constitute a hazard to navigation of ships in the area. For example, in waters 1000 feet deep the vertical cylinder **25** may have 900 feet extending above the ocean floor **12**, while several hundred feet are sunk in the ocean floor to anchor it securely in a vertical position. The vertical cylindrical structure may be in the order of 6 feet in diameter in its preferred form and as much as 2 inches in wall thickness to give it substantial rigidity. The vertical cylinder **25** may be originally transported to its offshore location on a series of barges or the ends of the cylinder **25** may be closed so as to aid in floating the structure to its desired location. The lower end of the vertical cylinder **25** may be jetted into the ocean floor in a manner well known to the art or it may be provided with a large diameter bit or series of bits mounted on a rotatable housing of the type well known to the art for drilling large-diameter holes. After drilling or jetting the lower end of the vertical cylinder **25** into place in the ocean floor, the walls at the lower end of the vertical cylinder **25** and/or the bottom thereof would be perforated so that cement could be pumped down the vertical cylinder **25**, out the perforations and up the annular space between the vertical cylinder and the ocean floor formations so as to cement the vertical cylinder or free-head pile **25** in place in a manner well known to the art.

Preferably, the vertical cylindrical structure **25** is provided with a buoyancy tank **26** near its upper end for maintaining a tension thereon. As shown in FIGURE 2, the vertical cylinder **25** is also provided at spaced intervals along its length with a plurality of radially-extending support plates **27**, **27***a* and **27***b* for supporting and securing the many flowlines, such as flowline **28** to the vertical cylindrical structure **25**. Thus, it may be seen that the vertical cylindrical structure **25** serves as substantially rigid support means for the major length of the many flowlines extending from the ocean floor **12** to the floating production facility generally represented by numeral **30** (FIG. 1) which floats on the surface of the ocean **26**. By using the vertical cylindrical support structure **25** of the present invention, a smaller floating production facility or a floating production facility with less buoyancy can be employed as the floating production vessel **30** only supports the flowlines between the vessels **30** and the top of the vertical cylinder **25** rather than having to support the thousands of feet of steel flowline extending from such a production vessel **30** to the various wells or production facilities on the ocean floor when the production vessel **30** is positioned in, say, 1000 feet of water. In the event that flexible flowlines are used, a greater number of support plates **27** would be employed as needed to prevent the flexible flowline from pulling apart under its own weight.

It is apparent that with floating production units, some motion of the platform is certain to occur regardless of how sophisticated a mooring system is used. This motion will chafe and deteriorate the lines hanging from the facility, and the loss hazard will be particularly high during stormy periods. If the lines are hanging free from the production facility deck, the lines are likely to part at or near the sea floor when failure takes place. However, when the lines are supported throughout a large portion of the sea floor to production facility deck interval of the present invention, with flexible pipe being used only for the free hanging portion between the top of the free-head pile and the production facility, the locus of failure is concentrated near the sea surface. Replacement of parted and damaged lines in this interval can be accomplished with relative ease and speed and at much less cost than if the failure had occurred at or near the sea floor. Thus, although use of floating production platforms probably necessitates accepting higher failure rates of flow lines and collecting and distribution lines, the economic consequences of these failures can be at least partially controlled by controlling the location of the failures by employing the apparatus of the present invention.

The floating production facility **30** may be a vessel of any suitable form which is maintained substantially directly over the elongated vertical cylinder **25** in any manner well known to the art. Thus, the production vessel **30** may be flexibly anchored in place by a series of anchors and anchor lines (not shown) or the vessel may be provided with a series of propulsion units adapted to move the vessel in any direction so as to maintain it substantially over the vertical cylinder **25**. One form of a production vessel may be triangular, as shown, with the hull made up of buoyancy cylinders **31**, **32**, and **33** at the corners while the interconnecting cross bracing members **34** are preferably hollow and form storage tanks for the oil produced from the wells until such time the oil is delivered to a tanker or barge **35**. In the event that gas is not separated from the production fluid at the ocean floor production facility **15** (FIGURE 1), the floating production vessel **30** is provided with suitable separating apparatus for separating gas and/or water from the oil produced. In addition to separators, the floating production vessel may be provided with heater-treaters or other demulsifying apparatus, metering tanks, etc. Although only two flowlines **37** and **38** are shown in FIGURE 1 as extending between the top of the vertical cylinder **25** and the production vessel **30**, it is to be understood that these

may be bundles of flowlines or other flowlines may extend individually between the vessel and the vertical cylinder **25**. In addition, power lines **39** extend from the production vessel **30** to suitable pumping apparatus whose power units are located at the top of the vertical cylinder **25**, as will be described hereinbelow.

As illustrated in FIGURE 1, the apparatus of the present invention may also include a series of interconnected storage tanks **40** to **45** preferably positioned in a frame **46** which in turn is anchored to the ocean floor **12**. A flowline **47** extends from the interconnected tanks **40** to **45** and includes an oil conduit extending up the vertical cylinder **25** and to the production vessel **30**. Thus, the ocean floor storage tanks **40** to **45** may serve as auxiliary storage capacity for the production vessel **30** in the event that the tanker **35** is delayed due to storms, etc. Any surplus oil that cannot be held in the storage tanks in the cross-members **34** of the production vessel **30** may be pumped down flowline **47** alongside the vertical cylinder **25** and into any of the tanks **40** to **45**. The oil could be returned to the vessel in any suitable manner as by means of sea-water displacement. The lowest point on the tanks is left open to the sea water to bleed off b. s. and w. (basic solids and water) and to equalize internal and external tank pressures to avoid bursting or collapsing the tanks. Therefore, it is necessary to pump crude oil into the tanks with a pressure equivalent to the difference between the sea water head and the crude oil head. For unloading the tanks, it is necessarly only to open a valve on the crude line at the surface to permit the sea water head to displace crude from the tanks. If withdrawal rates higher than those obtainable by sea water displacement are required, the flow rate can be increased by pumping or gas-lifting the crude. For emergency purposes, it may be desirable in some cases to arrange the flowlines and manifold in a manner such that the well production fluid passing through the flowline bundle **24** can flow directly into the storage tanks **40** to **45** in the event of power failures on the production vessel **30**. This could be done rather than shut in the wells.

As shown in FIGURE 2, a pump motor housing **50** is illustrated as being positioned on the top of the vertical cylinder **25** and secured thereto as by means of any suitable connector **51**. The pump housing is shown in greater detail in FIGURES 4 and 7 as enclosing one or more pump motors, in this case three pump motors **52**, **53** and **54** with the discharge lines **55** and **56** from the smaller pumps **52** and **53** being connected to the main discharge line **57** from the large pump **54** so that only one production fluid line **57***a* extends between the pump housing **50** and the production vessel **30**. The discharge lines **55**, **56**, and **57** may be provided with check valves **58** **59** and **60**. A plate **61** closes the bottom of the pump housing **50** and maintains it separated in a fluidtight manner from the interior of the vertical cylinder **25**. As shown in FIGURE 4 a discharge pipe **62** extends through the plate **61** and out through the wall of the pump housing **50** through a flexible line to the production vessel **30** so as to discharge any gases accumulating at the top of the vertical pile or cylinder **25** below the plate **61**. The electrical leads **39** may enter the pump housing **50** through the same wall as the pipe **57***a* (FIGURE 7). The pump motors **52**, **53** and **54** are arranged to drive shafts or rods **63**, **64** and **65**, respectively, of suitable centrifugal or deep well pumps **66**, **67** and **68**, respectively. Preferably, the capacities of the pumps are selected so that the large pump will run all the time and one or more of the small pumps will be run in an on-and-off manner so that the production fluid in the vertical cylinder **25** is maintained at the desired level. Preferably, the liquid level in the vertical cylinder **25** is maintained near the lower end thereof close to the inlet for the production fluid so that there is little hydrostatic head being applied to the low pressure-gas-oil separators at the production facility **15** (FIGURE 1). Hence, with or without employing the ocean-floor production facility **15** between the wellhead **11** and vertical cylinder **25**, by maintaining the level of production fluid low in the vertical cylinder **25** the wells would have less of a hydrostatic head against which to produce. Thus, it may be seen that by employing the vertical cylinder **25** of the present invention as a receiver having little or no hydrostatic head applied thereto, that low pressure wells could be produced, or old wells could be produced for a longer part of their life, before resorting to gas lift methods.

Any suitable type of liquid-level controller may be employed to control the liquid level within the vertical cylinder **25**. In one commercial form a liquid-level controller an open-ended pipe is immersed in the liquid body and air is pumped through. As the hydrostatic head builds up around the pipe and it is harder to discharge the air from the pipe, a sensing device on the vessel will indicate this change in liquid level and start one of the pumps which runs until the liquid level has been again reduced to the desired point. In FIGURE 4, the vertical cylinder **25** is shown as having a 2 inch line **69** extending down to a predetermined level above the uppermost pump **68**. This pipe **69** would be in communication with the vessel through a flexible line **70** (FIGURE 2). The pumps **66**, **67** and **68** are suspended from shaft housings **71**, **72** and **73** which surround the shafts **63**, **64** and **65**, respectively.

The pump housing **50** is removably secured to the top of the vertical cylinder **25** so that maintenance work can be done on the pumps as required. Although bolts could be unbolted by a suitable underwater manipulator as will be described hereinbelow, the housing may be provided instead with a suitable hydraulic or mechanical connector. One form of a suitable connector is shown in FIGURE 9 wherein the inner surface of the vertical cylinder **25** is provided with annular grooves **74** therein adapted to receive outwardly-extendible latching dogs **75** carried by a downwardly-extending wall **76** of the pump housing **50**. The wall **76** has formed therein an annular chamber in which an annular piston **78** is slidably mounted for a limited vertical movement. Hydraulic pressure can be supplied through conduits **79** or **80** to the top or bottom of the piston **72** to either lock or unlock the latching dogs **75** from the groove **74**. Thus, when it was desired to remove the pump housing and pumps from the vertical cylinder **25**, the latching dogs **75** of the connector **51** would be retracted and the whole housing and pumps would be pulled back to the production vessel by any suitable hoisting means.

Arranged near the bottom of the vertical cylinder **25** just above the ocean floor **12** (FIGURE 5) are one or more fluid inlet ports **82** through which production fluid is delivered to the vertical cylinder **25** from a production line **24***a* which in turn is connected to the ocean floor production facility **15** (FIGURE 1) or directly to one of the wells. The pipe **24***a* may be originally connected to the vertical cylinder **25** by lowering it by means of a line **83** into a V-grooved or U-shaped opening at the top of an aligning and support bracket **85** secured to the outer surface of the vertical cylinder **25**. A coupling **86** having an outwardly-extendible telescoping sleeve **87** is provided at the fluid inlet **82** in order to connect to the free end of the production line **24***a* in a fluidtight manner. The sleeve **87** may be moved outwardly in any suitable manner as by means of turning the actuating nut **88**. For this purpose an underwater manipulator may be employed which is either suspended from a track **90** secured to the outside of the vertical cylinder **25**, or may be of the type that rests on the ocean floor while carrying out operations. An underwater manipulator of this type is described in U.S. Patent 3,099,316 and includes a body member **91** provided with wheels **92** for propelling it around the track **90**, propulsion units **93** for moving it through the water, a support and/or power cable **94**, a unit **95** containing lights and a television camera, as well

as an extendible arm **96** having a wrench head **97** at the end thereof for manipulating various elements such as actuating bolt **88** on the connector **86**.

In FIGURE 6 the underwater manipulator device described with regard to FIGURE 5 is shown as being employed to connect another form of coupling **98** by turning its actuating screw **99** so as to connect lines **28** and **24***b* together in a fluidtight manner.

It may be seen from the above description that a method has been provided for producing deep water oil and gas field in which a plurality of wells have been drilled. The method includes the steps of installing a large-diameter vertical cylinder on the ocean floor with the upper end below the surface of the ocean, producing well fluids from the wells into the lower portion of the cylinder, providing a vessel on the surface of the ocean in the vicinity of the cylinder, connecting the interior of the cylinder in fluid communication with the vessel, and subsequently pumping well fluid from the cylinder to the vessel, preferably maintaining the level of the fluid in the cylinder in the lower portion thereof so as to reduce any hydrostatic head in the cylinder which would reduce the ability of the wells to produce under their own pressure. In addition, when the well production fluid contains gas the present method is altered to include the operation of separating the gas from the well fluid before the fluid enters the vertical cylinder. Alternatively, the method of the present invention includes the operation of separating a multiphase production fluid into its various components at the vessel on the surface of the ocean, and in the event that the storage capacity of the vessel is not sufficient, production fluid in the form of oil may be pumped back down to storage facilities on the ocean floor.

I claim as my invention:

1. A method of producing an underwater oil and gas field in which a plurality of wells have been drilled, said method comprising the steps of:

installing a large diameter vertical cylinder in the ocean floor and partially buoyantly supporting the upper end of said vertical cylinder below the surface of the ocean, producing well fluid from said wells into a lower portion of said cylinder,

providing a vessel on the surface of the ocean in the vicinity of the cylinder,

connecting the interior of the cylinder in fluid communication with the vessel, and

pumping well fluid from said lower portion of cylinder to said vessel.

2. The method of claim **1** wherein the level of well fluid in said vertical cylinder is maintained in the lower portion of said cylinder to reduce the hydrostatic head normally acting against the fluid being produced from an underwater well.

References Cited by the Examiner

UNITED STATES PATENTS

2,594,105	4/1952	Watts	114—0.5
2,731,168	1/1956	Watts	114—0.5
2,783,970	3/1957	Gillespie	166—0.5
2,990,796	7/1961	Cole et al.	61—46.5
3,063,507	11/1962	O'Neill et al.	166—0.5
3,111,692	11/1963	Cox	166—0.5

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

R. E. FAVREAU, *Assistant Examiner.*