United States Patent

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[54] **DEEP-WATER DRILLING, PRODUCTION AND STORAGE SYSTEM**

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[52] **U.S. Cl.**..**61/46.5**, 175/9

[51] **Int. Cl.**..**E02b 17/00**

[58] **Field of Search**.........61/46.5, 46, 50, 52; 175/9, 175/7

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[57] **ABSTRACT**

An offshore platform for drilling wells and producing oil from wells comprising a plurality of stacked annular concrete modules having concentric inner and outer walls enclosing a central opening that extends downwardly from the deck to the marine floor and a buoyancy chamber surrounding the central opening. The ends of the buoyancy chamber are closed to allow the modules to be floated to the well site. Means are provided to supply compressed air into the buoyancy chambers to control the amount of water in the buoyancy chambers to control the negative buoyancy of the platform and the load placed on the marine floor by the platform. The deck of the platform slopes downwardly from a curbing around its periphery to the central opening. Means are provided to lock the modules together into a unitary structure.

8 Claims, 9 Drawing Figures

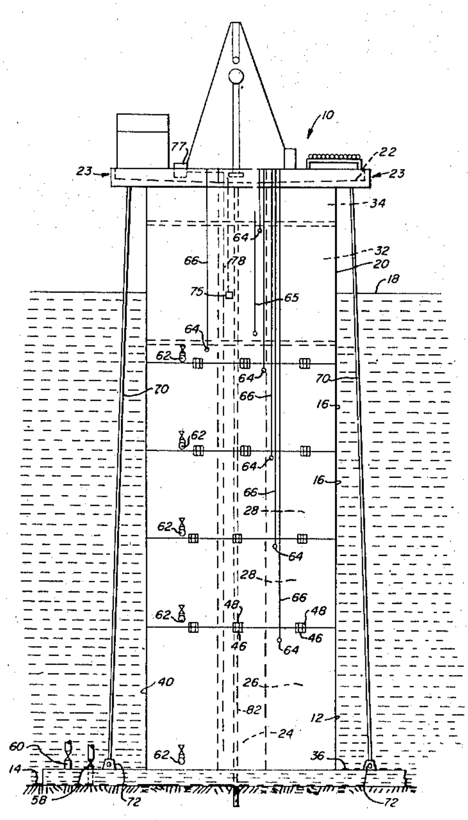

FIG. 1

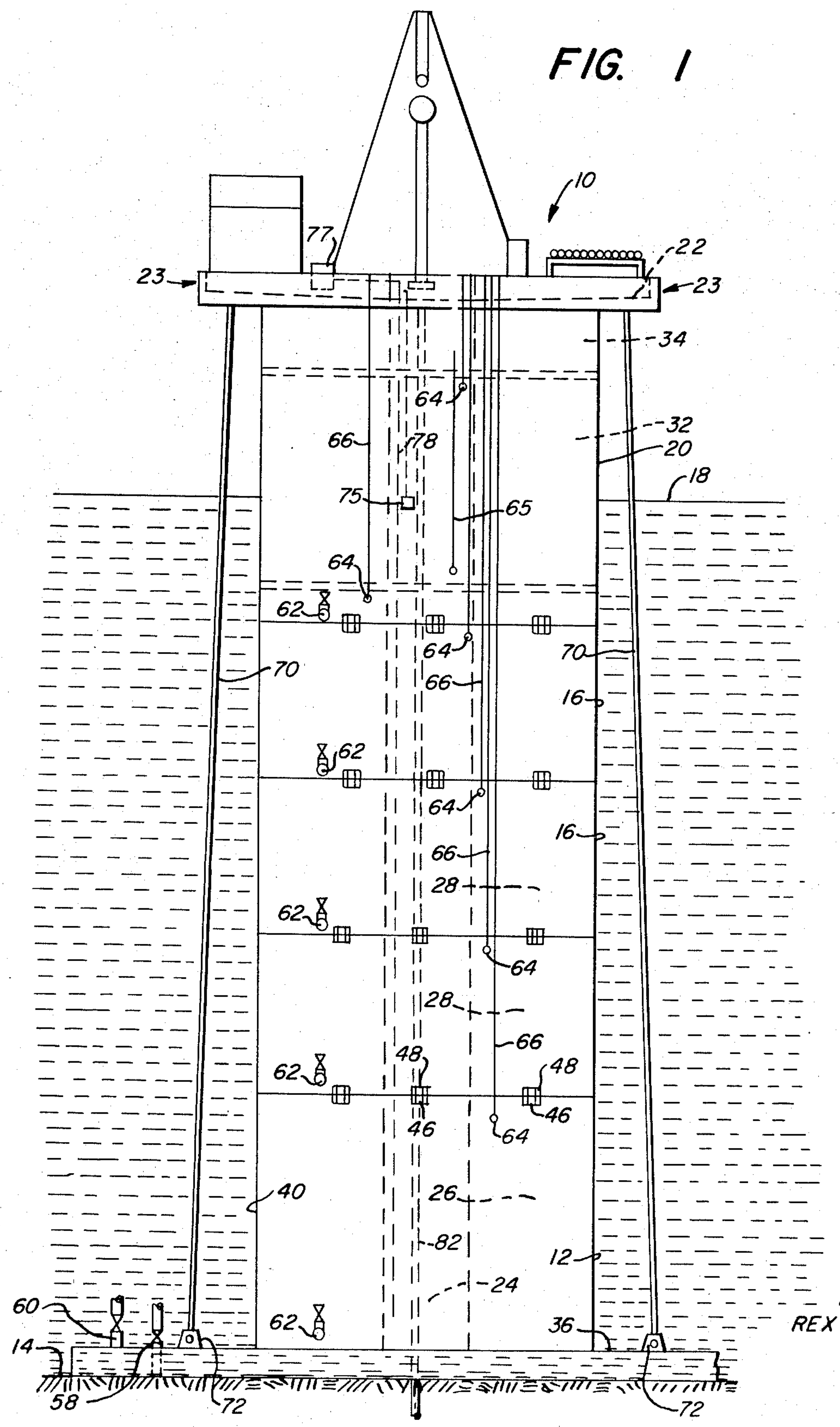

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FIG. 2a

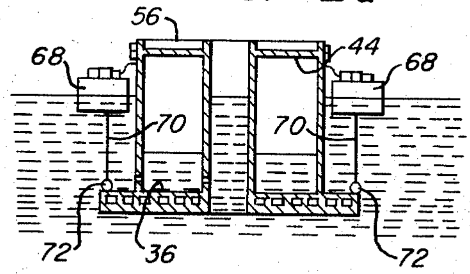

FIG. 2d

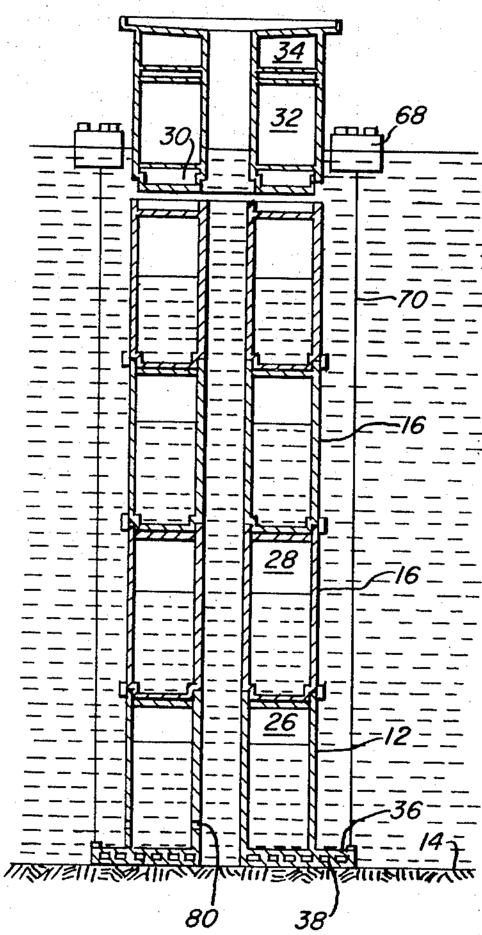

FIG. 2e

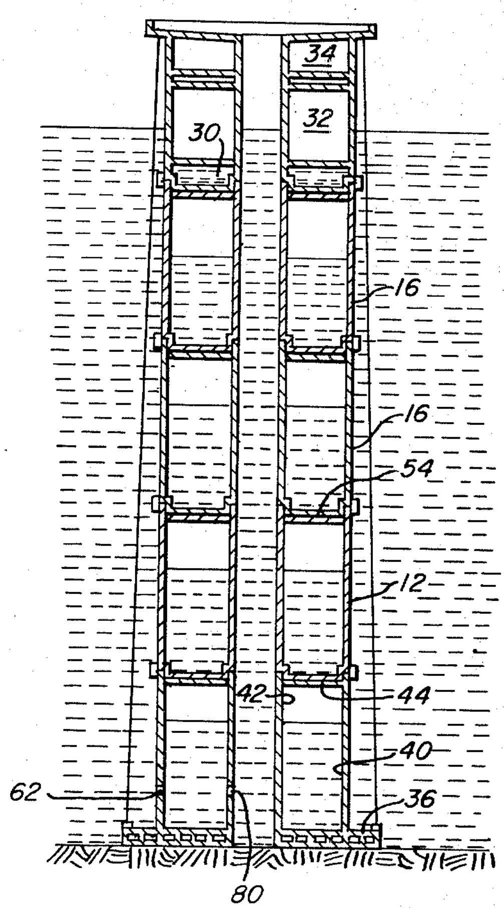

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FIG. 2b

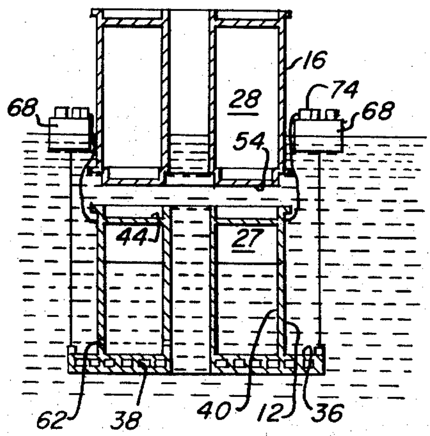


FIG. 2c

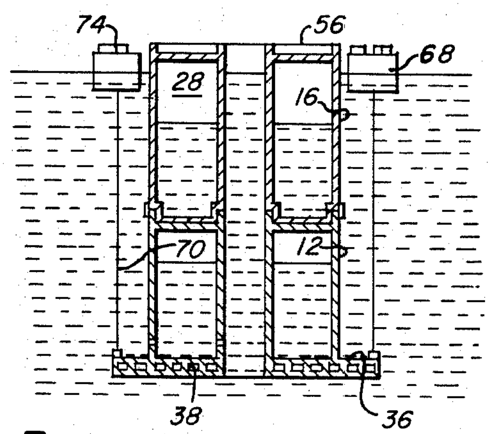


FIG. 3

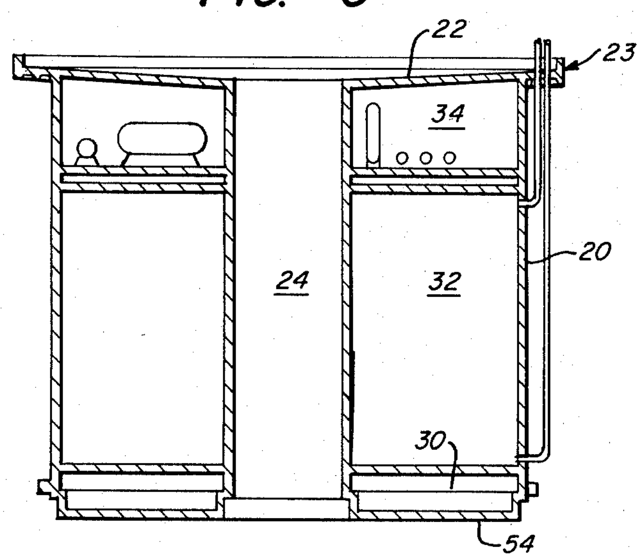


FIG. 5

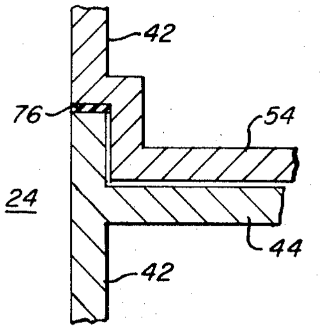
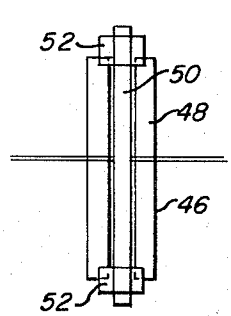


FIG. 4



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DEEP-WATER DRILLING, PRODUCTION AND STORAGE SYSTEM

This invention relates to the drilling of offshore wells for oil or gas, and more particularly to a platform and storage structure for such wells.

An important part of the world production of oil and gas is derived from offshore wells. It can be expected that the importance of production from offshore wells will increase in the future because exploration of the most promising areas for oil and gas has been much more extensive on land sites than offshore. As offshore production increases, wells will be drilled in deeper water at greater distances from the shore. Wells already have been drilled in water 370 feet deep from platforms supported by the marine floor. Such platforms are extremely expensive, and their cost will increase rapidly with an increase in the height of the platform necessitated by drilling in deeper water. Because the platforms are firmly anchored by legs extending downwardly into the marine floor to formations able to support the platform or to depths whereby friction of the legs with the soil provides a suitable support, they cannot readily be removed for use at other locations.

As wells are drilled in deeper water at greater distances from the shore, the problem of storing oil produced by the wells becomes more important. Unless the well produces from a large reservoir, a pipeline to shore is uneconomic. It then becomes necessary to provide storage at the well site with facilities for docking tankers which periodically take the oil from the storage facilities.

One problem that has become more serious in recent years because of rapidly increasing production of oil from wells located offshore is pollution of the ocean by oil spills. A platform structure which will confine oil spilled is an object of this invention. A further object is a stable structure capable of resisting storms and of being moved to other locations.

This invention relates to apparatus for supporting drilling rigs during drilling of offshore wells and production equipment during production of fluids from the wells and for storing produced oil in which a plurality of annular concrete modules are stacked on one another at the well site to provide a column extending from the marine floor to a deck supported above the surface of the water by the column. The central openings in the annular members are aligned vertically and form an opening extending downwardly through the center of the structure from the surface of the water to the marine floor. Each of the stacked modules has annular chambers surrounding the central opening and means to control the amount of water introduced into the chambers to permit adjustment of the negative buoyancy of the structure and the load on the marine floor. The modules interlock with one another and are provided with connecting means to form a rigid structure held in a compressed condition by cables extending from the bottom module to the deck of the platform. The modules from which the novel structure of this invention is assembled are prefabricated at a fully equipped shore installation and floated to the well site where they are sunk individually in a controlled manner to the desired depth by the introduction of sea water into the chambers of the modules. An annular chamber surrounding the central opening in the top modules serves as an offshore storage tank for oil.

In the drawings:

FIG. 1 is a diagrammatic elevational view of a platform, production, and storage structure constructed in accordance with this invention.

FIG. 2 is a series, (a) through (e), of diagrammatic vertical sectional views showing the steps for assembling the platform and storage structure at the well site.

FIG. 3 is a vertical sectional view of the top module.

FIG. 4 is a fragmentary view in elevation of a connection means that can be used for securing two modules together.

FIG. 5 is a fragmentary vertical sectional view showing means for sealing the juncture of two modules.

Referring to FIG. 1, the drilling platform, production and storage structure of this invention indicated generally by reference numeral **10** comprises a base module **12** resting on the ocean floor **14**. A plurality of intermediate modules **16** are stacked on base module **12** and one another to extend the structure **10** to a level a sufficient distance below the water level **18** to permit a top module **20** to be floated into position over the uppermost intermediate module **16**. Modules **12**, **16**, and **20** are constructed of reinforced concrete which may be prestressed.

Top module **20** extends upwardly a distance above the water level **18** to locate an upper deck **22** above the level of the highest waves that are likely to exist during storms. A curb **23** extends around the periphery of the deck. Each of modules **12**, **16** and **20** are of annular shape to form a centrally located vertical opening **24**, outlined by dotted lines in FIG. 1, extending from the marine floor **14** to the deck **22** when the modules are stacked in vertical alignment to form the structure **10**. The central opening **24** is surrounded by ring-shaped buoyancy chamber **26** in the base module **12** and buoyancy chambers **28** in the intermediate modules **16**, respectively, as is best shown in FIG. 2. An annular ballast chamber **30**, storage tank **32** and production equipment area **34** surround the central opening **24** in the top module **20**.

The base module **12** has a bottom member **36** that extends outwardly beyond the outer wall **40** of the buoyancy chamber **26** to provide a stable base for the structure **10**. Bottom member **36** is of cellular construction with a plurality of interior vertical walls **38** extending between the floor and the ceiling of the bottom member. Openings, not shown in the drawings, in the vertical walls **38** permit flow of water from one cell to another when the bottom member is flooded.

Both the outer wall **40** and inner wall **42** of buoyancy chamber **26** extend upwardly above the top **44** of that chamber to form a recess for interlocking the base module **12** with the adjacent intermediate module. Lugs **46** on the outer wall **40** near the upper end thereof and similar lugs **48** on the outer wall of the lower intermediate module **16** are in alignment to provide means for connecting the two modules. As shown in FIG. 5, the two modules are held together by a bolt **50** with nuts **52** that engage the ends of the lugs **46** and **48**. Any suitable latching means providing a positive connection of adjacent modules can be used.

The end walls closing the ends of the buoyancy chambers **28** of intermediate modules **16** extend downwardly below the ends of the inner walls and outer walls of the buoyancy chambers **28** to form an annular dowel **54** at the lower end and a recess **56** at the upper end for interlocking with adjacent modules of the structure **10**. Interlocking arrangements other than the dowell and recess structure are suitable if on lowering one module onto the adjacent module, part of one module bears against part of the other to hinder separation of the two modules by laterally directed forces. Each of the intermediate modules is fastened to the adjacent modules by suitable means such as the lug and bolt arrangement illustrated in FIG. **4**, and top module **20** is provided with means for interlocking with the uppermost intermediate module.

The bottom member **36** is provided with a port **58** shown in FIG. **1** through which a controlled weight of water can be delivered into the bottom member to provide the desired ballast as the base module **12** is towed to the well site and to aid in sinking the base module **12** at the well site. A vent **60** opens into the bottom member **36** to aid in filling the cells in the bottom member with sea water. Each of port **58** and vent **60** is provided with a valve or suitable other closure means to close the openings until the base module is to be sunk at the well site. Similarly, ports **62** open into the lower ends of each of the buoyancy chambers in the base module **12** and intermediate modules **16** and into the ballast chamber **30** of the top module **20**. Each port **62** is provided with a suitable closure member such as a valve to close the port until the module is to be sunk at the well site. A vent **64** opens into the upper end of each of the buoyancy chambers, the ballast chamber **30** and the storage tank **32**. Vent lines **66** extend from each of the vents **64** to the surface. An oil delivery line **65** extends from the production equipment area **34** to the lower end of the oil storage tank **32** for delivery of oil into, and withdrawal from, tank **32**.

Referring to FIG. **2***a* for illustration of the assembly of the platform **10**, the base module **12** is floated to the well site and is stabilized at that site between stabilizing barges **68**. Cables **70** from suitable winches on the barges are connected to brackets **72** on the upper surface of the bottom member **36**. Ports **58** in bottom member **36** and port **62** opening into buoyancy chamber **26** are opened. Vent **60** in the bottom member **36** is opened and vent **64** is connected through suitable manifolds on barges **68** to air compressors **74** mounted on the barges. Water is allowed to flow into bottom member **36** and buoyancy chamber **26** of base module **12** to sink the base module **12** to a level at which its upper end is at a depth below the surface of the water to permit an intermediate module **16** to be floated into position above the base module, as is shown in FIG. **2***b*.

When intermediate module **16** is in the position illustrated in FIG. **2***b*, the port **62** in the intermediate module is opened and the vent **64** connected through a suitable manifold to the air compressors on the barges **68**. Water is allowed to flow into the buoyancy chamber **28** to sink the intermediate module **16** onto the upper surface of the base module **12** with the dowel **54** on the lower end of the intermediate module nested in the recess **56** on the bottom module to interlock the two modules, as shown in FIG. **2***c*. As the intermediate module **16** sinks onto base module **12**, packing **76**, illustrated in FIG. **5**, on the upper end of the inner wall **23** of the base module is compressed to provide a seal between the two modules. A diver is lowered to install the bolts **50** engaging lugs **46** to connect the two modules together. Before each of the modules is sunk below the surface of the water, pipe is installed on each of the vent lines **66** to extend the vent line above the surface of the water for connection through suitable manifolds to the air compressors on the barges. As the modules are lowered, the increased hydrostatic pressure compresses the air in the upper end of the buoyancy chambers. Extension of the vent lines to the air compressors provides means for introducing additional air to maintain a constant or desired volume of air in the buoyancy chambers to maintain the desired negative buoyancy of the structure.

The procedure of sinking intermediate modules onto previously assembled modules is repeated the number of times necessary to position the upper end of the top intermediate module at a depth below the water surface permitting floating of the top module into position above the uppermost intermediate module while the bottom member **26** is resting on the marine floor **14**, as shown in FIG. **2***d*. The top module is floated into place and water admitted to the ballast chamber **30** of the top module to lower it until its dowel-shaped lower end rests in the recess at the upper end of the uppermost intermediate module. The top module is then locked into position by means of bolts **52** engaging lugs in that module and the uppermost intermediate module. The cables **70** extending from the stabilizing barges **68** are then connected to suitable anchors on the deck **22** and placed in tension. A drilling rig can then be installed on the deck **22** and production equipment in space **34**. The completed structure ready for the drilling rig is shown in FIG. **2***e*. In some instances, the desired height of deck **22** above the surface of the water may preclude complete fabrication of the top module **22** at the onshore site and floating it into position over the uppermost intermediate module. Top module **22** can be fabricated at the onshore site only to a midpoint of storage tank **32**, for example, floated into position, sunk onto the uppermost intermediate module, and then completed at the well site. It is desirable that the top module **22** be long enough to place the deck of the platform above the level reached by waves during the most severe storms likely to be encountered.

After assembly of the apparatus **10** at the well site and mounting of the drilling rig over the central opening **24**, a plurality of wells indicated by casing **82** are drilled downwardly by conventional techniques through central opening **24** into the oil reservoirs. It is contemplated that the central opening **24** will have a diameter of approximately **30** to **40** feet which will permit drilling a large number of wells from a single platform. The wells can be deflected outwardly to intersect the oil reservoir at locations spaced laterally at a substantial distance from the apparatus **10**.

After the wells have been completed, oil is produced from the wells and delivered into storage chamber **32**. Periodically the oil in storage tank **32** is transferred to a tanker or barge for delivery to an onshore terminal. If a leak should develop in any of the well equipment or equipment on the deck **22**, oil from the leak drains into the central opening **24**. A pump **75**, preferably located in the central opening at about water level **18**, is provided for removal of oil from the central opening. A pump **77** mounted on the deck **22** is connected to a line **78** extending downwardly into central opening **24** for removal of water from the lower end of the central opening to make room for spilled oil collected in the central opening. The oil collected in the lower end of central opening **24** is delivered into storage tank **32**. As an alternative to the pump **77** and line **78**, an opening **80** can be provided in the inner wall **42** to allow water to be displaced from the lower end of the central opening **24** through the ballast chamber and into the ocean. If there should be a leak around the casing of the well, leaked oil accumulates in the central opening from which it can be pumped to storage.

The drilling platform production and storage structure of this invention is a stable structure with controlled negative buoyancy firmly anchoring the structure to the marine floor. The large mass of the structure contributes to its large inertia and low frequency and low magnitude of oscillation to provide a structure capable of resisting high winds and waves. If it should be desirable to move the structure to another site, the stabilizing barges are returned to the site and compressed air is delivered into the ballast chamber to displace water from the chamber and thereby float the top module after disconnecting that module from the adjacent intermediate module. After removal of the top module, water is displaced from the buoyancy chambers to float the structure. The reverse of the procedure used in assembling is used to remove the modules individually.

It is an important advantage of this invention that the spilled oil is not allowed to spread on open water into very thin, difficult to recover, films. The oil caught in central opening **24** is isolated from wave action. Wave action makes satisfactory confinement of oil on open seas by floating barriers virtually impossible.

The diameter of the central opening in the annular modules, which may be as large as about 50 feet, and the length of the central opening combine to form an oil receiver capable of holding a large volume of oil. If the platform should extend 300 feet above the marine floor and the central opening be 50 feet in diameter, approximately 190,000 barrels of oil can be stored in the central opening. Because of the opening in the inner wall of the base module, the pressure inside and outside of the central opening are substantially equal, and substantially no tensile load is placed on the inner wall of the annular modules. The large diameter of the bottom member of the base module contributes to the stability of the platform.

When it is desired to move the platform to another location, the wells are plugged and all strings of casing cut at a level where they would be no hazard to shipping. Compressed air is introduced into the storage tank **32** and, if necessary, the ballast chamber **30** to displace liquid from those compartments to float the top module from the assembly after disconnecting the latching means securing the top module to the uppermost intermediate module. The cables **70** are disconnected from the top module. Air is then forced into the buoyancy chambers of the intermediate modules and, if necessary, the base module to float the assembly off the marine floor and raise the bottom of the uppermost intermediate module to a level convenient for disconnecting the latching means and floating the uppermost module off the assembly. The procedure is repeated until disassembly is completed and all of the modules floated. The modules can then be towed to another site and reassembled.

At no time during the assembly of the platform in accordance with this invention is it necessary to lift a module above the surface of the water. For that reason, the expense of large derrick barges can be avoided. The stabilizing barges only need to be equipped with winches and air compressors. Since the action of the winches and cables is stabilizing rather than lifting out of the water, the cost of the stabilizing barges is much less than of derrick barges large enough to lift prefabricated platforms above the water.

I claim:

1. A platform for offshore wells comprising a plurality of annular concrete modules stacked in alignment to form a column extending from the marine floor to above the wave level with a central opening having a diameter in the range of 30 to 50 feet extending from the upper end of the platform downwardly to the marine floor whereby a plurality of wells can be extended through the central opening, each of said modules having an inner wall extending for the full length of the module and surrounding the central opening, an outer wall concentric to the inner wall and spaced outwardly therefrom, a pair of spaced parallel end walls extending from the inner wall to the outer wall of each module to close the space therebetween and define a buoyancy chamber in each of the modules of a volume adequate to float the module when the buoyancy chamber is filled with air, means for introducing water into the buoyancy chamber of each of the modules in an amount adequate to sink the module, means for removing water from the buoyancy chambers to control the buoyancy of the modules, latching means joining each of the modules to adjacent modules to form a unitary structure, and means for removing water from the lower end of the central opening to provide space in the central opening for liquids draining into the upper end of the central opening, said modules including a base module, intermediate modules, and a top module, the inner walls of the stacked modules forming a continuous unbroken wall around the central opening from the top module to the bottom module, the base module having a bottom member extending laterally beyond the outer wall thereof, said bottom member having ballast chambers therein and means for introducing water into the ballast chambers, and said top module having a deck at its upper end sloping downwardly from its outer edge to the central opening for drainage into the central opening.

2. A platform as set forth in claim **1** in which the means for removing water from the lower end of the central opening comprise a passage through the lower portion of the inner wall of the base module, and the means for removing water from the buoyancy chamber of the base module includes a passage through the outer wall near the lower end of said module whereby water can be displaced from the lower end of the central opening through the buoyancy chamber to the water surrounding the platform.

3. A platform as set forth in claim **1** in which the means for removing water from the lower end of the central opening include a pump mounted on the platform and a pipe connected with the pump and opening at its lower end into the lower portion of the central opening.

4. Apparatus as set forth in claim 1 including a plurality of cables secured to the base module extending upwardly therefrom and secured under tension to the top module.

5. A platform for offshore wells comprising a plurality of annular concrete modules stacked in alignment to form a column extending from the marine floor to above the wave level with a central opening approximately 30 to 50 feet in diameter extending from the upper end of the platform downwardly to the marine floor, said modules having an inner wall surrounding the central opening and an outer wall concentric to the inner wall and spaced therefrom, a pair of spaced parallel end walls extending from the inner wall to the outer wall to close the space between the inner and outer walls and define a buoyancy chamber in each of the modules whereby the modules float when the buoyancy chambers are full of air, means for introducing water into the buoyancy chambers, means for removing water from the buoyancy chambers to control the buoyancy of the modules, latching means joining each of the modules to adjacent modules to form a unitary structure, said modules including a base module, intermediate modules, and a top module, a passage laterally through the base module permitting flow of water surrounding the platform to and from the central opening, and tension cables secured to the base module and extending upwardly to and connected to the top module to hold the modules in the stacked arrangement.

6. A platform for offshore wells comprising a plurality of annular concrete modules stacked in alignment to form a column extending from the marine floor to above the wave level with a central opening extending from the upper end of the platform downwardly to the marine floor, said modules having an inner wall surrounding the central opening and an outer wall concentric to the inner wall and spaced therefrom, a pair of spaced parallel end walls extending from the inner wall to the outer wall to close the space between the inner and outer walls and define a buoyancy chamber in each of the modules whereby the modules float when the buoyancy chambers are full of air, means for introducing water into the buoyancy chambers, means for removing water from the buoyancy chambers to control the buoyancy of the modules, latching means joining each of the modules to adjacent modules to form a unitary structure, said modules including a base module, a plurality of intermediate modules, and a top module, the base module having a bottom member of

substantially larger diameter than the intermediate modules, a storage tank in the top module between the inner and outer wall thereof, means for delivering oil into and withdrawing oil from the storage tank, a production equipment compartment between the inner and outer wall of the top module and above the storage tank, a deck at the upper end of the top module sloping from the outer edge thereof toward the central opening, and a curbing around the periphery of the deck.

7. A method of constructing an offshore platform for an oil well comprising floating a base module to the well site, flooding compartments in the base module to sink the base module to a first intermediate depth at which the bottom of the base module is above the marine floor and the top of the base module is submerged to a depth just allowing a first intermediate module to float above the base module, floating a first intermediate module above the base module, flooding a buoyancy chamber in the intermediate module to sink the first intermediate module onto the base module and submerge the intermediate module to a second intermediate depth permitting a second intermediate module to be floated above the first intermediate module, latching the first intermediate module to the base module, floating a second intermediate module into position above the first intermediate module, flooding a buoyancy chamber in the second intermediate module to sink that module onto the first intermediate module and lower the three modules to a second intermediate depth at which the top of the second intermediate module is at a depth below the surface of the water adequate to float an intermediate module thereabove, latching the second intermediate module to the first intermediate module, repeating the steps of sinking modules onto the assembled modules, latching the modules, and lowering the assembled modules until the base module rests on the marine floor and the top of the uppermost intermediate module is below the surface at a depth permitting a top module to be floated thereabove, floating a top module into position above the uppermost intermediate module, latching the top module and supporting the modules at the desired depth during each step by cables secured to the bottom module extending upwardly to barges to the uppermost intermediate module.

8. A method as set forth in claim 7 in which the cables are connected to the top module and placed in tension after the top module has been sunk onto the assembled modules.

* * * * *